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THESIS

CALCULATION OF ATMOSPHERIC TRANSMITTANCE
BY IBM 3033 COMPUTER CODE LOWTRAN IIIB

by

Moon-Sik Shin

June 1983

Thesis Advisor:

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T208950

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Calculation of Atmospheric Transmittance by IBM 3033 Computer Code LOWTRAN IIIB		5. TYPE OF REPORT & PERIOD COVERED Master's thesis; June 1983
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Moon-Sik Shin		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Naval Postgraduate School Monterey, California 93940		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS Naval Postgraduate School Monterey, California 93940		12. REPORT DATE June 1983
		13. NUMBER OF PAGES 101
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		15. SECURITY CLASS. (of this report)
		15a. DECLASSIFICATION/ DOWNGRADING SCHEDULE
16. DISTRIBUTION STATEMENT (of this Report) Approved for public release; distribution unlimited.		
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)		
18. SUPPLEMENTARY NOTES		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) LOWTRAN transmission aerosol		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) LOWTRAN IIIB is a FORTRAN computer program for prediction of atmospheric optical transmittance, developed at the U. S. Air Force Geophysics Laboratory (AFGL). LOWTRAN IIIB was received in the modified form developed by Naval Weapons Center China Lake for use on the UNIVAC 1110 computer (Ref. 1), and has now been interfaced to the IBM 3033 computer. Due to compiler storage limitation in the IBM computer the atmospheric data are read into common storage at the beginning of the program. The two		

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Comparisons of NPS LOWTRAN IIIB computations with direct optical extinctions measurement over Monterey Bay and at San Nicolas Island indicate that under these circumstances LOWTRAN IIIB underestimates the extinction due to aerosols while the computed molecular absorption is in substantial agreement with experiment.

LOWTRAN IIIB is presently available as a method of predicting atmospheric transmittance at low resolutions at NPS and is suitable for incorporation in simulations and studies of electro-optic weapon/sensor systems performance.

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Calculation of Atmospheric Transmittance
by
IBM 3033 Computer Code LOWTRAN IIIB

by

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Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN PHYSICS

from the

NAVAL POSTGRADUATE SCHOOL
June 1983

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ABSTRACT

LOWTRAN IIIB is a FORTRAN computer program for prediction of atmospheric optical transmittance, developed at the U.S. Air Force Geophysics Laboratory (AFGL). LOWTRAN IIIB was received in the modified form developed by Naval Weapon Center China Lake for use on the UNIVAC 1110 computer [Ref. 1], and has now been interfaced to the IBM 3033 computer.

Due to compiler storage limitation in the IBM computer the atmospheric data are read into common storage at the beginning of the program. The two dimensional block data submodule has been replaced with a linear data array, and a new subroutine (array) written to reformat the data. The basic logic structure is unchanged.

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ACKNOWLEDGMENT

I wish to express my appreciation to the Air Force Korea for opportunity to study in the subject area of this thesis.

I would like to express my sincere appreciation to Professor A. Cooper for his endless patience and willingness to stop whatever he was doing and provide much needed guidance. His positive attitude and encouragement were a tremendous support.

The assistance of Professor G. E. Schacher in making his data available for comparison is greatly appreciated.

I would also like to thank Professor E. Milne for his efficient assistance and the faculty of the Physics Department for the instruction I received during my course of study at the Naval Postgraduate School.

Finally, I would like to thank my loving wife, So-Young, my cute daughter, Hui-Won, and my son, Dong-Joon, for their faith, encouragement, and prayers during the past year.

I. INTRODUCTION

LOWTRAN IIIB is a FORTRAN computer program, developed at the U.S. Air Force Geophysics Laboratory (AFGL), which was received in the modified form developed by Naval Weapon Center. It calculates the transmittance of the earth's atmosphere in the spectral region from 0.25 to 28.57 micrometers (350 to $40,000$ cm^{-1}) at 20 cm^{-1} spectral resolution on a linear wavenumber scale. Six atmospheric models, which are tropical, midlatitude summer and winter, subarctic summer and winter, and the U.S. 1962 standard atmosphere, covering seasonal and latitudinal variations from sea level to 100 km are available, in addition to a capability of allowing the user to input atmospheric parameters of his own choosing. The program includes four aerosol models which are average continental, urban, rural, and maritime, and either hazy (5 km visibility) or clear (23 km visibility) haze conditions can be selected in addition to the capability of selecting a particular visibility of the user's choosing. The model accounts for molecular absorption, molecular scattering, and aerosol extinction, plus atmospheric refraction and earth curvature effects.

LOWTRAN IIIB is presently an available method for predicting atmospheric transmittance at low resolution at NPS and may be incorporated in simulations and studies of electro-optic weapon/sensor systems performance.

Basically, this thesis describes a program to

a) Develop a computer code to calculate atmospheric transmittance for particular wavelengths.

b) Develop a code to give transmittance and molecular absorptance with bandwidth appropriate to grey-body sources.

c) Apply these to prediction of transmittance over a marine optical path, based on the available meteorological data base for the area, for conditions appropriate to the optical propagation experimental measurement program at the Naval Postgraduate School.

II. THEORY OF ATMOSPHERIC TRANSMITTANCE

Beer's law for linear propagation of monochromatic radiation in the linear regime can be expressed as follows;

$$\frac{d}{dz} [I(\nu)] = -\mu(\nu) I(\nu) \quad (\text{eqn 2.1})$$

or

$$I(z) = I(0) e^{-\mu z} \quad (\text{eqn 2.2})$$

The ratio $\frac{I(z)}{I(0)}$ is defined as the transmittance T of the path of length z , and μ is the total extinction coefficient which is the sum of the coefficients for total absorption and non-forward scattering

$$\mu = \mu_a + \mu_s$$

Both the scattering and absorption coefficients can be divided into components due to the molecules of the air and the aerosol particles suspended in it; i.e.

$$\mu_a = k_m + k_a$$

$$\mu_s = \sigma_m + \sigma_a$$

where k_m = molecular absorption coefficient

k_a = aerosol absorption coefficient

σ_m = molecular scattering coefficient

σ_a = aerosol scattering coefficient

The relative values of the four coefficients depend strongly on the density and molecular composition of the atmosphere and the composition, number density and size distribution of the aerosols. The order of importance in each of the important atmospheric transmission windows is shown in Table I [Ref. 2]. We note from this that scattering by both

molecules and aerosols is of greater importance in the visible, and absorption in the infrared (particularly 8 to 14 μm). Since devices are designed to operate throughout these windows, it is important to predict the transmittance of the atmosphere as a function of wavelength and weather conditions. This prediction becomes a complex problem of computer modelling. The problem requires a definition of the composition, density and pressure of the atmospheric gases, together with the frequencies, line strengths and line widths of all the spectroscopic transitions of the gas molecules and the aerosol constituents, and the number, size

TABLE I
Optical Atmospheric Attenuation Coefficient

Atmospheric window	Wavelength for EO systems (μm)	Attenuation Coefficients in order of importance
Visible	0.4 - 0.7	σ_a, σ_m, K_a
Near Infrared	0.7 - 1.2	$\sigma_a, K_a, \sigma_m, K_m$
Middle Infrared	3.0 - 5.0	$K_m, \sigma_a, K_a, \sigma_m$
Far Infrared	8.0 - 12.0	K_m, K_a, σ_a

and composition distributions of the particles.

Over the entire wavelength range from visible to infrared the absorption by molecules, scattering by aerosols and absorption by aerosols are the dominant extinction mechanisms, and should be considered. In the "window" regions of good transmittance, the molecular line absorption is relatively small, and may in some regions be ignored. The remaining extinction in these regions is due to aerosol scattering (which varies only slowly with wavelength) and "continuum absorption" by the molecules.

A. MOLECULAR ABSORPTION

To compute the monochromatic transmittance of the atmosphere, we must first obtain accurate data describing the frequencies, intensity and line shape of all absorption lines affecting the attenuation. These should be developed a compilation based on certain constraints dictated by atmospheric abundances if we need to develop this monochromatic capability.

The approach by AFGL is to calculate the transmittance at given wavelength for each transition having finite absorption at that wavelength for each of the molecules. The summation over all the molecules gives a monochromatic transmittance which is appropriate directly for laser propagation, but must be degraded by integration over finite bandwidth for low resolution predictions suitable to non-laser sources.

To calculate the transmittance $T = e^{-K_m z}$, the absorption coefficient K_m should be known as a function of frequency for each line.

The four essential line parameters for each line are the resonant frequency, ν_0 (cm⁻¹), the intensity per absorbing molecule, S (cm⁻¹/molecule cm⁻²), the Lorentz line width parameter, $\mathcal{L}_0$ (cm⁻¹/atm), the energy of the lower state, E'' (cm⁻¹), and the line half-width at half maximum, $\mathcal{L}$, which is proportional to the pressure. The frequency, ν_0 , is independent of both temperature and pressure. The molecular absorption coefficient is given by

$$K_m(\nu) = \frac{S \mathcal{L}}{\pi [(\nu - \nu_0)^2 + \mathcal{L}^2]} \quad (\text{eqn 2.3})$$

$$S = \int K_m(\nu) d\nu \quad (\text{eqn 2.4})$$

The pressure broadened line width depends in a complicated fashion on temperature; for computation this is approximated by the assumption of temperature - independent collision diameters, leading to

$$\mathcal{L} = \mathcal{L}(P_0, T_0) \frac{P}{P_0} \left(\frac{T_0}{T}\right)^{\frac{1}{2}} \quad (\text{eqn 2.5})$$

where $P = 1$ atm, and

$T = 296$ degrees Kelvin.

The intensity, S , is pressure-independent and its temperature dependence can be calculated from E'' and

$$S(T) = S(T_0) \frac{Q_v(T_0)}{Q_v(T)} \times \frac{Q_r(T_0)}{Q_r(T)} \times \exp \left[1.439 E'' \left(\frac{T - T_0}{TT_0} \right) \right] \quad (\text{eqn 2.6})$$

where Q_v and Q_r are vibrational and rotational partition functions respectively. At lower pressure the collision broadening diminishes and Doppler broadening becomes important. In the intermediate pressure range the Voigt profile obtained by convolving the two profiles is used. Once Doppler broadening dominates the Gaussian profile may be used. Lorentz linewidths are typically .001 to .01 cm^{-1} , while the Doppler width may be 0.0003 cm^{-1} .

The AFCRL calculations [Ref. 14] are based on the Absorption Line Parameters Compilation, which originally listed ν_0 , $S(T)$, $\mathcal{L}(P_s, T_s)$ and E'' for 130,000 lines in the range beyond 1 μm , for each one of the species water, carbon dioxide, ozone, nitrous oxide, carbon monoxide, methane and oxygen. A new version of the compilation including over 139,000 lines between 0.2 μm and 30 μm was recently reported by AFGL [Ref. 3].

B. CONTINUUM ABSORPTION

Continuum absorption occurs as a result of collisional interactions between molecules; that is, collisions between two H_2O molecules and those of other gases (principally H_2O : N_2 collision, since nitrogen comprises approximately 80 % of the air)

In wavelength regions between the absorption bands some attenuation occurs of a continuous nature which is attributed to water vapor. The mechanism of water vapor continuum extinction lacks a complete theoretical explanation. At present, it is believed that it results from the accumulated attenuations of the distant wings of H_2O absorption lines, occurring principally in the far infrared part of the spectrum. Other postulates, such as that the phenomenon is caused by other absorption mechanisms involving H_2O dimers, remain possibilities yet to be proved.

However, all that we can do at present is to account for the water vapor continuum phenomenon empirically, based on what limited experimental measurements we have to go on, until better line shape theories become available. It should be emphasized that further accurate and well controlled measurements are urgently required in order to account for this phenomenon in real atmospheric situations with confidence.

A common formulation used (for example in LOWTRAN IIIB) to account for the water vapor continuum attenuation at a fixed temperature has been to define the transmittance $\bar{T}(\nu)$ as follows;

$$\bar{T}(\nu) = e^{-K(\nu) \times \text{range}} \quad (\text{eqn 2.7})$$

where the attenuation coefficient $k(\nu)$ is given by

$$K(\nu) = C_s \left[P_{H_2O} + \frac{C_N}{C_s} (P_T - P_{H_2O}) \right] \omega \quad (\text{eqn 2.8})$$

where P_{H_2O} and P_T refer to the water vapor partial pressure and ambient pressure respectively (atm), and ω defines the quantity of water vapor per unit pathlength (gm cm⁻² km⁻¹). The quantities C_s and C_N are generally referred to as the self and foreign (nitrogen) broadening coefficients for water vapor.

Values for C_s and C_N/C_s have been obtained empirically from laboratory measurements. In LOWTRAN versions I through III, the quantity C_N/C_s is assumed to remain constant over a given wavelength interval. However, a major addition in LOWTRAN IIIB has been to account for the temperature dependence of C_s and this will be discussed in the 8-14 μm H_2O continuum region. The H_2O continuum radiation in the 3.5-4.2 μm region is of much less importance and will not be further discussed here.

1. Temperature Dependence

The water vapor continuum attenuation coefficient has been found to have a significant temperature dependence, which was not accounted for in the previous LOWTRAN computer codes. Based on the laboratory measurements using samples of water vapor at elevated temperatures, an approximate empirical expression was obtained by Roberts et al [Ref. 6] for the temperature dependence which is given in Eqn 2.9 below. It was found that the attenuation coefficient due to the water vapor continuum increases as the temperature decreases. That is, for a fixed amount of water vapor in a given path, one would expect more absorption at lower temperatures and less absorption at higher temperatures. This is a somewhat unusual phenomenon. In practice one finds less water vapor in the atmosphere under cold conditions, therefore, the effect of temperature on the attenuation in

the 8-14 μm region plays two competing roles, through the total water content of the path and the attenuation coefficient.

The empirical fits to the wavelength and temperature dependence of the water vapor continuum described in Roberts et al [Ref. 6] have been used in LOWTRAN IIIB with the appropriate conversion of units as follows.

The attenuation coefficient C_s in $\text{gm}^{-1} \text{cm}^2 \text{atm}^{-1}$ at 296 K is given by the following expression in the 8-14 μm region:

$$C_s(\nu, 296) = 4.18 + 5578 \exp(-7.87 \times 10^{-3} \nu) \quad (\text{eqn 2.9})$$

where ν is the wavenumber in cm^{-1} (note that $\nu = 10^4 / \lambda$, where λ is the wavelength in μm).

The temperature dependence of the coefficient C_s was found to vary as:

$$C_s(\nu, T) = C_s(\nu, 296) \exp 6.08 \left(\frac{296}{T} - 1 \right) \quad (\text{eqn 2.10})$$

where T is the temperature in degrees Kelvin.

2. Nitrogen Broadened Coefficient

C_N/C_s in the above Equation represents the ratio of the foreign (nitrogen) broadening coefficient to the self broadening coefficient.

In LOWTRAN IIIB we use a value of 0.002 for the parameter C_N/C_s based on the measurements presented by Supplement LOWTRAN IIIB [Ref. 7].

Here, it is assumed that C_N/C_s (at 296 K) does not vary with temperature (since no supporting measurements are available).

Thus, further measurements are needed to determine more accurately the magnitude of the parameter C_N/C_S and its temperature and wavelength dependence.

3. Transmission Calculations

The transmittance due to the water vapor continuum in the 8-14 μm region is calculated for a horizontal path of length RANGE(km) at altitude z using the following expression in LOWTRAN IIIB:

$$T(\nu) = \exp[-C(\nu, 296) \times W(z) \times \text{RANGE}] \quad (\text{eqn 2.11})$$

where $W(z)$ is the effective H_2O absorber amount per unit path length (in $\text{gm} \cdot \text{cm}^{-2} \text{atm km}^{-1}$) at altitude z , and $C_S(\nu, 296)$ is the water vapor (self broadened) attenuation coefficient obtained from laboratory measurements at a temperature of 296 K.

The quantity $W(z)$ is given by:

$$W(z) = w(z) \left[P_{\text{H}_2\text{O}} \exp \left[6.08 \left(\frac{296}{T(z)} - 1 \right) + 0.002 (P_T - P_{\text{H}_2\text{O}}) \right] \right] \quad (\text{eqn 2.12})$$

where

$w(z)$ = $\text{gm cm}^{-2}/\text{km}$ of H_2O in the path at temperature T ,
 $P_{\text{H}_2\text{O}}$ = H_2O partial pressure (atm) at altitude z ,
 P_T = ambient (total) pressure (atm) at altitude z , and
 $T(z)$ = ambient temperature at altitude z (degrees Kelvin).

Note that the temperature dependence of the attenuation coefficient $C_S(\nu, T)$ given in Eqn 2.10, has been incorporated into the expression for W in Eqn 2.12. The reason for this

is so that the temperature variation over a given atmospheric slant path is weighted equally with the water content along the path.

It may be worth contrasting Eqn 2.12 with the corresponding expression which has been used in LOWTRAN I through LOWTRAN III, that is:

$$W(z) = w(z) \left[P_{H_2O} + 0.005 (P_T - P_{H_2O}) \right] \quad (\text{eqn 2.13})$$

C. AEROSOL EXTINCTION COEFFICIENT & MODELS.

Scattering of radiation occurs from molecules in the air, from aerosol particles suspended in the air, and from water droplets in fog, rain or hail. The attenuation of a beam depends on the size and number density distribution and the refractive index of the particles. Atmospheric transmission may be strongly influenced or even dominated by scattering from aerosol particles. The major parameter determining the interaction is the ratio of particle radius to the wavelength of the radiation.

1. Aerosol extinction coefficient

Aerosol extinction is sum of the absorption and scattering by aerosol particles. Although scattering by aerosol particles whose radius is smaller than about 0.03 times the wavelength of the light may be calculated by Rayleigh theory, for the whole range of particle radius Mie theory must be applied.

a. Rayleigh Scattering

The Rayleigh volume total scattering coefficient may be written as

$$\sigma_m = \frac{8\pi^3(n^2-1)^2}{3N\lambda^2} \left(\frac{6+3P}{6-7P} \right) \quad (\text{eqn 2.14})$$

where n ; refractive index
 N ; the number density of molecules
 P ; depolarization factor due to some molecular anisotropy.

Following Penndorf [Ref. 8] it can be written in the following form which depends on pressure and temperature.

$$\sigma_m = 9.807 \times 10^{-20} (273/T) (P/1013) \nu^{4.017} \text{ Km}^{-1} \quad (\text{eqn 2.15})$$

The strong dependence on wavelength means that Rayleigh scattering is a small effect for wavelengths longer than the visible.

b. Mie scattering

This is appropriate for the condition of particle size comparable to wavelength; i.e., for large molecules and small droplets. This is the most important mechanism for atmospheric scattering. McCartney gives the scattering coefficient [Ref. 9].

$$\sigma = \pi \int r^2 N_T(r) K(\lambda, n) dr \quad (\text{eqn 2.16})$$

where r ; the particle radius

$N_T(r)$; the total number density of particles in the size range dr about r

$K(\alpha, n)$; the area scattering coefficient, the ratio of effective area to geometrical area, which depends on $\alpha = 2\pi/\lambda$ and refractive index n .

2. Aerosol Model

The range of conditions in the boundary layer is represented by three different aerosol models, which are rural, urban or maritime. The first two are grouped together as "averaged continental".

a. Maritime

Maritime aerosol composition and size distributions are significantly different from rural and urban aerosol types. The maritime aerosol component is due to salt particles which are caused by the evaporation of seaspray droplets. The concentration of particles near the surface is strongly dependent on wind speed (above 7 m/sec) and the size distribution is also dependent on relative humidity. This salt-particle number-density decreases rapidly above about 500 m [Ref. 10].

b. Rural

Rural aerosol background is partly the product of reactions between various gases in the atmosphere and partly due to dust particles picked up from the earth surface. The particle concentration is largely dependent on the history of the air mass carrying the aerosol particles.

c. Urban

Urban aerosols contain certain additives from combustion products and from industry. Shettle and Penn assumed an addition of 35% soot-like particles of similar distribution to the rural aerosol [Ref. 11].

III. LOW RESOLUTION MODELLING

A. MODEL ATMOSPHERES

The LOWTRAN code provides a choice of six atmospheric models. These include the 1962 U. S. Standard Atmosphere plus five supplementary models. Surface level conditions for the supplementary models are given in Table II [Ref. 1]. There are also two conditional haze models - corresponding to sea level visual ranges of 5 and 23 km - provided as basic input data for LOWTRAN III. Aerosol attenuation for other visual ranges is calculated using an interpolation/

TABLE II
Surface Level Condition for Model Atmospheres

Model atmosphere	Latitude & month	Pressure (mb)	Temp. (K)	Air density (g/m ³)	Water vapor (g/m ³)	Ozone (g/m ³)
Subarctic winter	60 N, Jan	1013	257	1372	1.2	4.1E-05
summer	60 N, July	1010	287	1220	9.1	4.9E-05
Midlatitude winter	45 N, Jan	1018	272	1301	3.5	6.0E-05
summer	45 N, July	1013	294	1191	14.0	6.0E-05
Tropical	15 N	1013	300	1167	19.0	5.6E-05

extrapolation procedure which utilizes these two models. In addition to the model atmospheres the user has the option of inserting his own model atmosphere, or of building another model by combining various parts of the six standard models.

Provisions are made in the LOWTRAN program for inserting radiosonde data. There are limits on the accuracy of LOWTRAN transmittance calculations when the input is radiosonde data alone. Radiosondes provide vertical profiles of the synoptic meteorological parameters of temperature,

pressure, humidity, and wind. Information on micrometeorological parameters (i.e., aerosol size distributions, local oxidant concentrations, etc.) is also needed as input. In the absence of micrometeorological inputs LOWTRAN relies on its model atmospheres for that information; this may not necessarily be applicable to a specific location. For further discussion on optical parameters see [Ref. 12].

E. CALCULATION MODELLING

In the application it is impossible to measure transmittance at a single frequency. Instead one measures the transmittance $T(\nu)$ averaged over the spectral bandwidth, $\bar{T}_{\Delta\nu}(\nu)$, accepted by the receiver, as indicated in the equation

$$\bar{T}_{\Delta\nu}(\nu) = \frac{1}{\Delta\nu} \int T(\nu) d\nu \quad (\text{eqn 3.1})$$

where ν is the central frequency in the interval, $\Delta\nu$. Consequently for many applications one is interested in knowing the transmittance of the atmosphere averaged over a relatively wide spectral interval, that is, for low resolution.

Thus the term transmittance is somewhat ambiguous unless it is qualified by some indication of the spectral resolution, $\Delta\nu$, over which it is averaged. This is particularly true in the case of molecular absorption, since the absorption coefficient K_m is a rapidly varying function of frequency. It is because of the rapid variation of K_m with frequency that the averaged transmittance $\bar{T}$ does not, in general, obey the simple exponential law. That is,

$$\bar{T}_{\Delta\nu}(\nu) = \frac{1}{\Delta\nu} \int_{\Delta\nu} \exp[-K_m(\nu) \Delta m] \quad (\text{eqn 3.2})$$

where K_m represents the net monochromatic molecular absorption coefficient. On the other hand the molecular scattering coefficient ($\bar{\sigma}_m$) and the aerosol scattering and absorption coefficients (σ_a and K_a) are slowly varying functions of frequency, and the average transmittance obeys the simple exponential law provided only the direct transmitted beam is being observed

There are four basic approaches to obtaining a low resolution transmittance value for a given path through the atmosphere due to molecular absorption. These are;

- (1) direct measurements over the required path,
- (2) measurements in the laboratory under simulated conditions,
- (3) line-by-line (monochromatic) calculations based on detailed knowledge of spectroscopic line parameters which are then averaged over the required spectral interval, and
- (4) calculations based on band model techniques (which use available laboratory and/or field transmittance measurements or actual line data as a basis).

From the point of view of computations, method 3 involves a considerable amount of work and computer time, and consequently method 4 has been used most frequently.

Basically, it involves a graphical or computerized "curve fitting" technique for accessing the stored transmittance data for the appropriate absorber and scatterer amounts computed from the input atmospheric path conditions. The predetermined variations of transmittance with frequency are stored for the various atmospheric constituents, for standard path conditions.

For a given set of meteorological conditions and selected path, the appropriate absorber and scatterer amounts in the required path are computed for each component and the results used to correct the transmittances for these components. The transmittances for the separate processes

(line absorption, continuum absorption, molecular scattering, aerosol scattering and aerosol absorption) are then multiplied together to give the overall absorption. That is :

$$T_{\Delta\nu}(\nu) \text{ (total)} = T_{\Delta\nu}(\nu) \text{ (line absorption)} \times \\ T_{\Delta\nu}(\nu) \text{ (continuum absorption)} \times \\ T_{\Delta\nu}(\nu) \text{ (Rayleigh)} \times \\ T_{\Delta\nu}(\nu) \text{ (aerosol)}.$$

It should be noted that the LOWTRAN computer code is designed to calculate the transmittance for spectral bands. It should not be used to calculate transmission for laser lines. Suitable techniques for computing atmospheric transmission for laser lines or extremely narrow spectral bands are described in [Ref. 13], [Ref. 14], and [Ref. 15].

IV. EXAMPLE OF PROGRAM USE

A. PROBLEM

As a check on the performance of the code a sample calculation was carried out using the same input data described by Shlanta and Cornette [Ref. 1], for which they provide computed output.

The example is the calculation of the transmittance from 2350 to 2450 cm^{-1} in steps of 5 cm^{-1} for a slant path from 2.5km to 8.5 km at a zenith angle of 65 degree, for a subartic winter model atmosphere, and a 23 km visual range.

The program is initiated with data input on 4 cards (lines) defining the conditions of the computation, and user directions are given at the beginning of the program listing (Appendix A).

CARD 1 **5**1**1

5 ; Sub-artic winter atmosphere

1 ; An average continental aerosol model

1 ; For 23 km visible range

0 ; For normal operation, etc.

CARD 2 **2**0*****2.500*****8.500****65.000

2 ; Vertical & slant path between two altitudes

0 ; For normal operation of the program which
selects the shorter path when applicable

2.500 ; Observer altitude (km)

8.500 ; Source altitude (km)

65.000 ; Zenith angle at H1 (deg.).

CARD 3 **2350.000**2450.000*****5.000

2350.000 ; Initial frequency (cm^{-1})

2450.000 ; Final frequency (")

5.000 ; Frequency intervals at which
transmittance is printed.

0 ; To end data.

B. OUTPUT FROM LOWTRAN IIIB.

The output for this problem is given in Appendix C. The parameters defining the atmospheric path, model atmospheres and frequency range are first printed out. Following tabulations give the absorber amounts for horizontal and vertical path. At the heading HORIZONTAL PROFILES there are 13 columns. The first column gives a running integer associated with each level. The second column gives the level altitude in km. The next 8 columns give the equivalent absorber amounts per km for the following absorbing species: water vapor, uniformly mixed gas, ozone, nitrogen continuum, water vapor continuum (10 μ m), molecular scattering, aerosol extinction and UV ozone, respectively. The next three columns give the mean refractive index modulus from that level to the level above, the equivalent absorber amounts per km for the water vapor continuum (4 μ m) and for nitric acid.

A heading VERTICAL PROFILES is then printed followed by 15 columns. The first and second columns give the integer associated with the levels traversed by the path and the height of the level. Then follow 8 columns which give the integrated equivalent absorber amounts from the initial altitude to the level above (in the same order as indicated above). The next 4 columns are labelled PSI, PHI, BETA, and THETA (see Appendix D).

The total equivalent absorber amounts for each absorber species are then summarized below in their appropriate units.

The second line in the total equivalent absorber amount table gives the water vapor continuum amount (4 μm) and the nitric acid amount.

A transmittance table, containing 12 columns, now follows. The first 3 columns give the frequency (cm^{-1}) wavelength (μm), and total transmittance. The next 7 columns show the individual transmittances due to water vapor, uniformly mixed gases, ozone, nitrogen (4 μm) continuum, total water vapor continuum, molecular scattering, and aerosol extinction. The last 2 columns give absorption due to aerosols and the cumulative integrated absorption. The latter quantity can be used to determine the average transmittance over any given spectral interval within the spectral range covered by the calculation. Finally, the total integrated absorption from V1 to V2 is printed out together with the average transmittance over the band.

V. APPLICATION

The purpose of this implementation of LOWTRAN IIIB is to present a simple method of predicting atmospheric transmittance (at low resolution) which is applicable over a wide spectral interval and for a wide range of atmospheric path.

In this study the bandwidths of the computations have been chosen to match the transmission bands of the filters used by the atmospheric optics measurement group at NPS [Ref. 16]. These filters have been used with grey - body sources to give wavelength resolution in a number of trans-

TABLE III
Broadband System

center wave- length (μm)	filter bandwidth at $1/2$ ht (μm)	" (CM^{-1})	grey-body source temp. (K)	detector
0.49	.010	20619-21053	2800	Si
0.63	.010	15748-16000	"	"
0.84	.010	11834-11976	"	"
1.03	.010	9662-9756	"	"
1.06	.010	9390-9479	"	"
1.60	.098	6064-6447	"	"
2.15	.097	4549-4759	"	Ge
3.80	.400	2500-2778	1800	InSb, 77K
3.835	.110	2571-2646	"	"
10.66	2.850	827-1083	"	HgCdTe, 77K
11.02	.710	879-938	"	"

mittance measurements at Monterey and elsewhere. Figure 5.1 shows the passbands of the grey-body source filters superimposed on curves of atmospheric transmittance for a 1000 ft, path at sea level containing 5.7 mm of precipitable water at 79°F. The filter bands are shown as Table III.

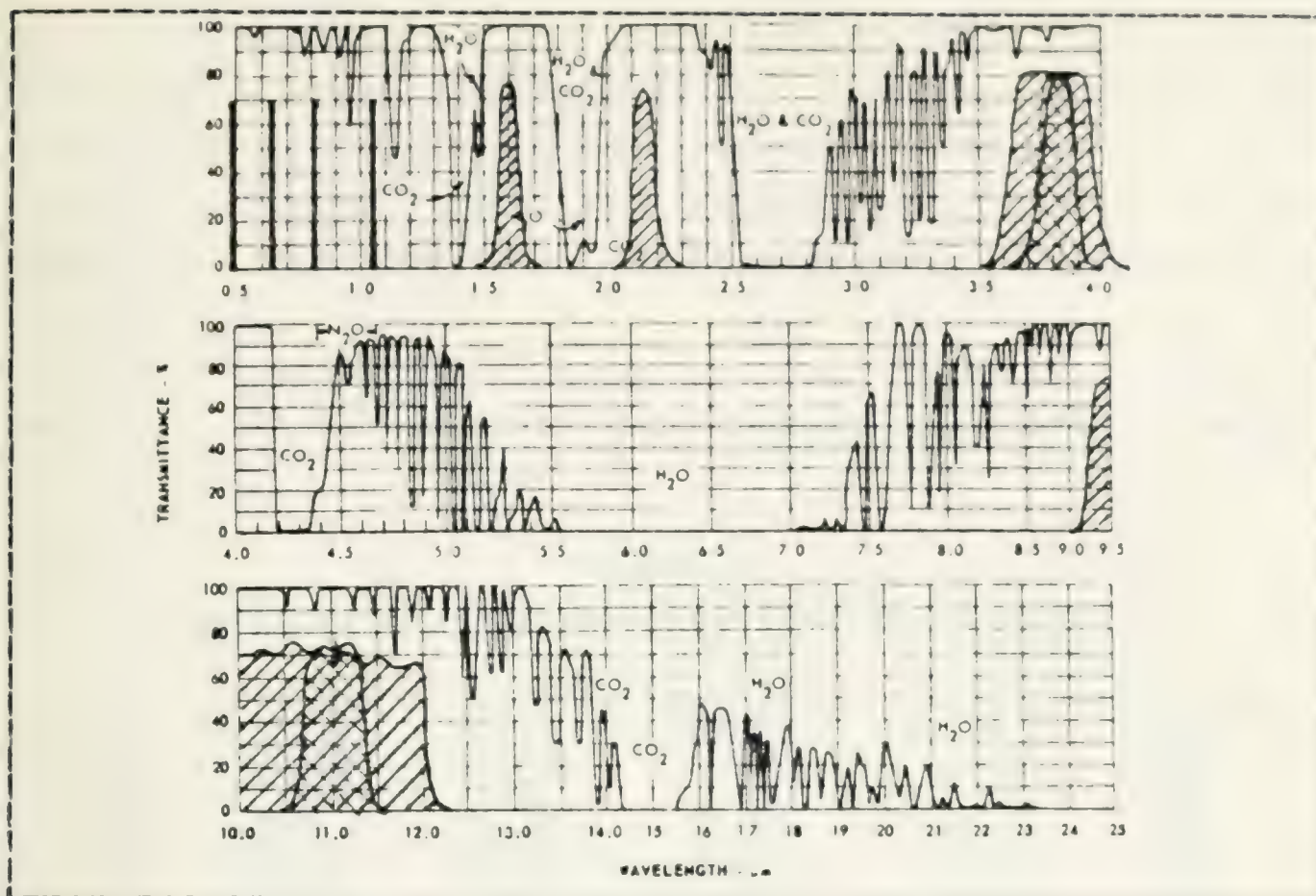


Figure 5.1 Bandpass Regions for Grey-body Source.

A. LOWTRAN CALCULATIONS FOR THE MONTHLY AVERAGE DATA OF MONTEREY BAY

Calculations intended for use in the propagation studies in the Monterey Bay Area make use of the known range of conditions and three different relative humidities, 70, 80, and 90 %, taking into account the monthly and yearly averages of air pressure, air temperature, dewpoint temperature, water vapor density, and relative humidity. These monthly and yearly averages are taken from the thesis by Guner [Ref. 4], and ozone density is translated from that source to $6.00\text{E-}05 \text{ gm/m}^3$, consistent with the midlatitude model in Table II. In this Table IV the average temperature is used which is the mean value of maximum and minimum average temperatures corresponding to day/night conditions.

Table V shows the calculated atmospheric transmittance for 3 different cases of relative humidities and temperatures for selected wavebands of the broadband system at sea level (1.60, 2.15, 3.80, 3.835, 10.66, 11.02 μm), 13.16 km range, and with typical May conditions. Figure 5.2 and Figure 5.3 also represent the atmospheric transmittance of Table V.

By comparing the numbers for different relative humidity, it can be seen that increasing relative humidity

TABLE IV
Monterey Bay Area Average Weather Condition

	mean pr. (mbars)	mean temp. (deg.)	mean dew. (deg.)	H2O den. (gm/M)	rel. hum. (%)
JAN.	1020.0	10.03	6.12	7.37	77
FEB.	1020.0	10.57	6.68	7.67	76
MAR.	1017.5	10.84	6.68	7.67	78
APR.	1018.0	11.68	8.34	8.53	77
MAY.	1017.0	13.34	9.45	9.11	77
JUN.	1015.0	14.45	11.12	10.16	79
JUL.	1017.0	14.73	11.68	10.55	83
AUG.	1017.5	15.29	10.23	10.92	84
SEP.	1013.5	15.84	14.73	10.55	79
OCT.	1017.5	14.73	10.01	9.40	75
NOV.	1019.0	12.79	7.23	7.95	72
DEC.	1018.0	11.12	6.12	7.37	73
YEAR.	1017.5	13.07	8.89	8.82	77

TABLE V
Comparison of Transmittance by R.H & Temperature

	μm	wavenumber cm-1	Rel. Humidity			temperature ($^{\circ}\text{C}$)		
			70 %	80 %	90 %	0.0	13.3	30.0
(1)	1.60	6064-6447	.823	.823	.823	.823	.823	.823
(2)	2.15	4549-4759	.834	.832	.831	.833	.833	.833
(3)	3.80	2500-2778	.803	.797	.791	.794	.799	.803
(4)	3.835	2571-2646	.813	.808	.803	.806	.810	.814
(5)	10.66	827-1083	.836	.815	.793	.801	.821	.839
(6)	11.02	879-938	.856	.833	.808	.818	.840	.860

decreases the atmospheric transmittance. We can also see that increasing temperature increases the transmittance;

significant differences of the transmittance occur due to temperature. The numbers from the 8-14 μm region are much larger than the other band. This point is consistent with the theory of the temperature dependence from chapter II.



Figure 5.2 Comparison of Transmittance due to Relative Humidity.

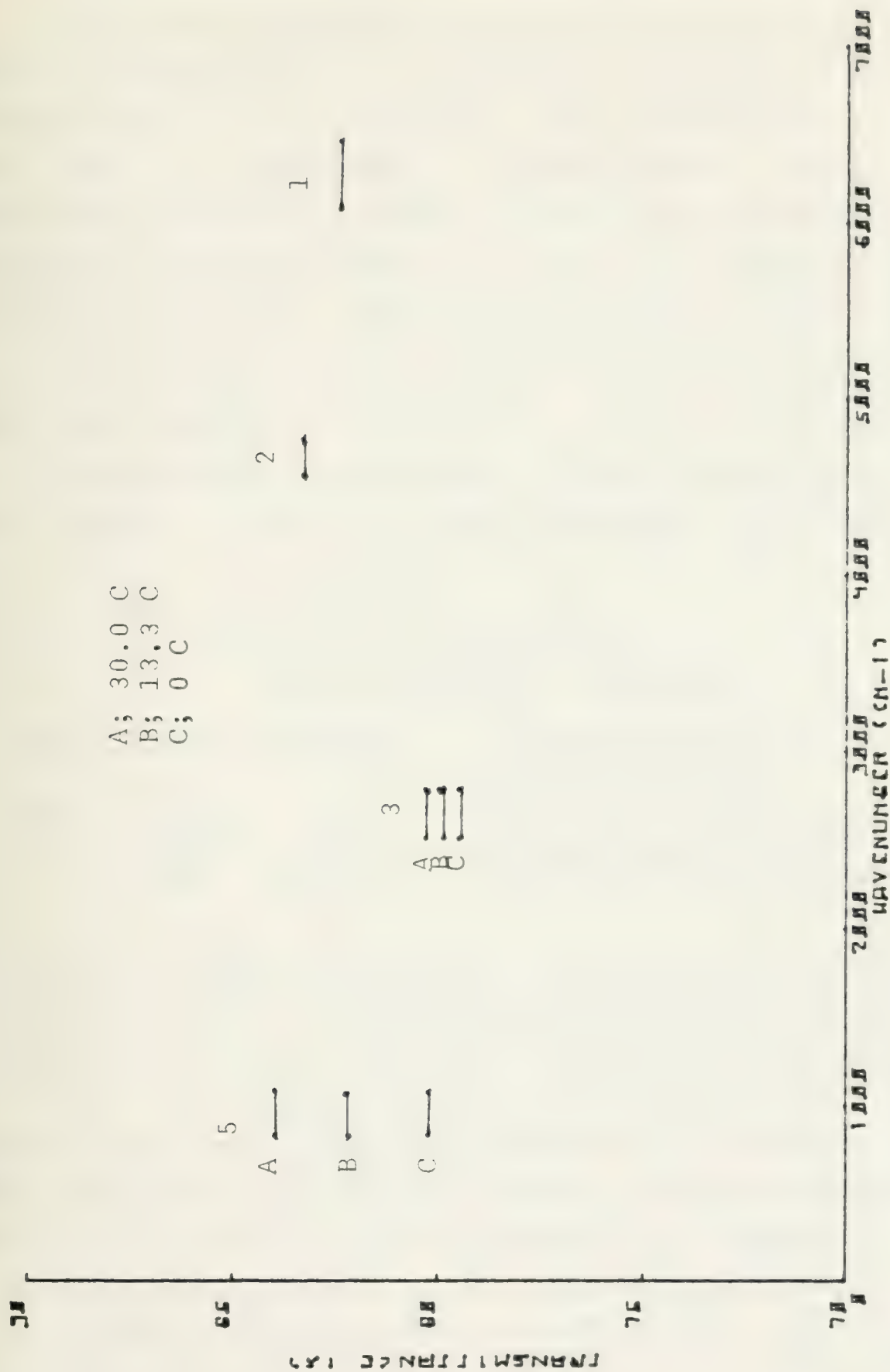


Figure 5.3 Comparison of Transmittance due to Temperature.

B. OPTICAL TRANSMISSION AT SAN NICOLAS ISLAND, CEWCOM-78.

In May 1978 the NPS Optical Physics and Micrometeorology Groups participated in a Cooperative Experiment, West Coast, Oceanography and Meteorology, 1978 (CEWCOM-78) in cooperation with the measurement program OSP-III run by the USN Optical Signatures Program on San Nicolas Island. Optical transmittance measurements from the R/V ACANIA to shore and micrometeorological measurements on the R/V ACANIA were made by NPS measurement group, and other meteorological data were monitored in the OSP experiment. Weather conditions limited the data obtained.

The measured transmittance of the optical path from the R/V ACANIA to site A on the northwest tip of San Nicolas

TABLE VI
San Nicolas Data, CEWCOM-78

Date	Time	Range (m)	Broadband (μ m)	
			3.6-4.0	9.0-12.0
5/15	1126		63.0 % (94.99)	
"	1458	2192		45.2 % (96.14)
"	1633	2200	57.8 % (95.31)	
"	1649	2200		49.8 % (96.63)

Island is listed in Table VI. The transmittances are the observed values, uncorrected for the molecular absorption, measured with filter selection from a grey-body source.

The micrometeorological data taken by the NPS Meteorology Team during the CEWCOM-78 experiment [Ref. 16] and the Daily Statistical Summary of Meteorological Data [Ref. 17] are used to find interpolated temperature, relative humidity, and visibility. The numbers in parentheses represent LOWTRAN predictions of transmittance, including both molecules and aerosol extinction based on these meteorological input data.

The comparison is given for the one day for which suffi-

TABLE VII
Meteorological Data

Time	Broadband (μm)	Press. (mbar)	Temp. (deg.)	Dew T. (deg.)	R.H. (%)	Water vapor (g/m ³)
1126	3.6-4.0	1013.2	14.52	10.0	81.0	9.8
1633	"	"	14.99	10.9	66.7	"
1458	9.0-12.0	"	14.80	10.9	74.67	9.7
1649	"	"	14.93	10.0	65.69	9.5

cient meteorological data are available (Table VII). This comparison shows the LOWTRAN predicted transmittance for these conditions to be much higher than the measurements. The overestimation of transmittance by LOWTRAN suggests that the particle model included in the code may be inadequate, or that the model's total particle number density may be underestimated by the code. Calibration errors in the measurement equipment have been investigated and are considered an unlikely source of the discrepancy.

C. EXPERIMENTAL MEASUREMENT FROM MARINA TO POINT PINOS

The current modelling effort was undertaken in support of an experimental program of transmittance measurement of total extinction on ranges over Monterey Bay from Marina to Point Pinos (June 1979) using laser and broadband (thermal) sources. The optical extinction was measured at 0.4880, 0.6328, 1.03, 1.06, and 11.05 μm .

The calculational program has therefore been directed to computation of molecular absorption and aerosol extinction coefficients for sea level propagation under a range of weather conditions statistically typical of Monterey. This has been done for a variety of wavelengths appropriate to the measurements, and averaged over the filter bandwidths for the broadband sources used (see Table III.).

The aerosol particle spectrum was measured on board the ACANIA with a Knollenberg counter. This information was used to predict a scattering extinction coefficient, based on one point measurement of the particle size spectrum.

For comparison of data it is necessary to subtract the effects of molecular absorption from the total optical

TABLE VIII

Extinction Coefficient from Optical Measurement and LOWTRAN

date time		optical	LOWTRAN		diff.	aerosol
		(μm)	(a)	(b)	(c)	(d)
6/6	1734	1.60	22.5	2.47	0.072	22.4
	1714	1.06	21.7	2.68	0.165	21.5
	1718	1.03	19.4	2.69	2.63	16.8
	1720	0.84	22.1	2.75	0.196	21.9
	1721	0.63	22.5	2.83	0.066	22.4
6/7	1406	11.02	19.17	1.84	1.52	17.7
	1404	10.6	12.1	2.01	1.49	10.6
	1423	1.06	35.5	2.45	0.16	35.3
	1434	1.03	43.9	4.87	2.56	41.3
	1555	11.02	20.0	1.73	1.25	18.8
	1558	10.6	10.6	1.77	1.26	9.34
	1615	1.6	35.3	2.17	0.07	35.2
	1628	1.06	38.3	2.43	0.15	38.2
	1632	1.03	35.0	4.69	2.4	32.6
	1634	0.84	40.1	2.52	0.18	39.9
	1636	0.63	43.2	2.45	0.067	43.13
						7.62
						7.72
						48.7
						49.5
						7.83
						7.71
						49.2
						50.5
						51.4
						51.0
						53.0

extinction. This is done using LOWTRAN. The value of relative humidity and water vapor content have been obtained from Prof. Schacher and Dr. Fairall who made the aerosol measurements [Ref. 18].

The results are presented in Table VIII. The extinction in units of E-02 km^{-1} as measured optically, the LOWTRAN prediction of total extinction, the molecular contribution computed by LOWTRAN, total measured minus LOWTRAN molecular, and the values calculated from aerosol spectra are shown.

By the comparison seen by the Table VIII, optical extinction computed from the aerosol spectra is much higher than the LOWTRAN total extinction, and is very often higher

than the measured optical extinction. This may be due to the fact that aerosol extinction was not measured over the whole path but at only one point. It was measured on board the ACANIA meteorological mast at a height of approximately 10 m above mean sea level, at approximately the centerpoint of the optical path. The optical path in this experiment ranged from 18.3 m above sea level at Marina to almost sea level at the ACANIA, due to earth curvature over the 13.16 km path.

Total aerosol extinction from LOWTRAN is much less than the extinction calculated from the measured aerosol spectrum. Subtracting the calculated molecular component of the LOWTRAN from the optically measured extinction yields the aerosol extinction ("diff."), which is much greater than the LOWTRAN aerosol component but somewhat less than that predicted from the aerosol spectra. i.e., agreement of aerosol extinction is much better with aerosol spectrum measurement than with the LOWTRAN aerosol extinction. It appears probable that the LOWTRAN model consistently underestimates the severity of aerosol extinction in the marine environment.

VI. CONCLUSION AND RECOMMENDATION

The comparisons of LOWTRAN IIIB predictions with optical measurements and with computations from particle size distribution measurements show considerable differences. The differences could conceivably arise from measurement errors in the optical transmittance and the particle measurements; the two physical measurements give results reasonably close to each other but in both cases differ markedly from LOWTRAN IIIB. In view of the consideration give to both measurement techniques it seems most likely that LOWTRAN IIIB consistently underestimates the aerosol attenuation in the infrared wavebands

It must first be realized that LOWTRAN IIIB contains limitations. It does not include the effects of

1. clouds, fog or precipitation
2. refraction, scintillation or distortion of the propagating beam due to turbulence
3. background interference from direct or scattered solar radiation
4. surface level reflections and masking
5. multiple scattering

In addition the models of refraction and earth curvature are simplified and the atmosphere is considered to be horizontally homogeneous and stable with no inversion. These limitations mean that at best LOWTRAN IIIB results are of "moderate" accuracy.

Some of these limitations have been removed in the continuing evolution of LOWTRAN. LOWTRAN IV (Feb. 1978) in addition to using improved empirical transmittance functions for gases of small absorber amount, includes the effects of nitric acid as an absorber and emitter, and incorporates a

"radiance mode" to compute the radiance from the earth surface and the atmosphere.

LOWTRAN V (Feb, 1980) has been upgraded to include new aerosol models dependent on altitude and relative humidity, and a model for fog attenuation.

It may be expected that implementation of these codes (preferably LOWTRAN V) may give better agreement between experiment and computation and allow better validation of aerosol extinction calculation methods.

LOWTRAN IV and LOWTRAN V are not currently available at NPS in card or tape form, and considerable modification will be required to adapt them to use on the IBM 3033 system. In the absence of later forms of LOWTRAN, the IIIB version may still be used to compare transmittances under different conditions. In addition, little change has been made in the absorption in later versions, so that the use of IIIB to compute the atmospheric absorption is valid. This allows its use to compute aerosol extinction from total optical extinction by subtraction of the calculated absorption.

It is recommended that an effort should be made to adapt LOWTRAN V for the NPS IBM computer system.

LOWTRAN IIIB PROGRAM

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```

C* IAERO = 2 SPECIFIES A RURAL AEROSOL MODEL.
C* IAERO = 3 SPECIFIES AN URBAN AEROSOL MODEL.
C* IAERO = 4 SPECIFIES A MARITIME AEROSOL MODEL.
C*
C* IHAZE SELECTS THE DEGREE OF AEROSOL ATTENUATION.
C* IF IHAZE=0 NO AEROSOL SCATTERING IS COMPUTED.
C* IF IHAZE = 1 AND VIS IS NON-ZERO, THEN AEROSOL ATTENUATION
C* FOR THE VISIBLE RANGE IS USED.
C* IF IHAZE = 1 OR 2 AND VIS IS ZERO, THEN AEROSOL ATTENUATION
C* FOR 23 KM AND 5 KM VISIBLE RANGES, RESPECTIVELY,
C* IS USED.
C*
C* JP SELECTS THE PRINT OPTION.
C* JP = 0 FOR NORMAL OPERATION.
C* JP = 1 TO SUPPRESS THE PRINTING OF THE TRANSMITTANCE TABLE.
C*
C* IM DETERMINES WHEN RADIOSONDE DATA IS TO BE READ IN.
C* IM = 0 FOR NORMAL OPERATION.
C* IM = 1 FOR INITIALIZING RADIOSONDE OR METEOROLOGICAL
C* DATA.
C*
C* M1, M2, AND M3 ARE USED TO CHANGE TEMP, H2O, AND O3 ALTITUDE
C* PROFILES, RESPECTIVELY, TO ANOTHER MODEL VALUE.
C*
C* ML IS THE NUMBER OF LEVELS OF RADIOSONDE DATA FOR MODEL = 7.
C*
C* R0 IS THE INPUT VALUE FOR THE RADIUS OF THE EARTH. IF R0 IS
C* ZERO THEN THE PROGRAM USES STORED VALUES.
C*
C* VIS IS THE VISUAL RANGE AT SEA LEVEL (KM)
C*
C* *** CARD 2: ITYPE, LEN, H1, H2, ANGLE, RANGE, BETA---FORMAT(2I3,4X,5F10.3) ***
C*
C* ITYPE INDICATES THE TYPE OF ATMOSPHERIC PATH.
C* ITYPE = 1, CORRESPONDS TO A HORIZONTAL (CONSTANT PRESSURE)
C* PATH. READ H1 AND RANGE.
C* ITYPE = 2, VERTICAL OR SLANT PATH BETWEEN TWO ALTITUDES.
C* READ H1 AND TWO OTHER GEOMETRIC PARAMETERS (E.G., H2 AND
C* ANGLE).
C* ITYPE = 3, VERTICAL OR SLANT PATH TO SPACE.
C* READ H1 AND ANGLE.
C*
C* LEN SELECTS THE TYPE OF RAY PATH TO BE USED.
C* LEN = 0 FOR NORMAL OPERATION OF THE PROGRAM WHICH SELECTS
C* THE SHORTER PATH WHEN APPLICABLE.
C* LEN = 1 TO SELECT THE LONGER PATH WHEN APPLICABLE.
C*

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07330
07340
07350
07360
07370
07380
07390
07400
07410
07420
07430
07440
07450
07460
07470
07480
07490
07500
07510
07520
07530
07540
07550
07560
07570
07580
07590
07600
07610
07620
07630
07640
07650
07660
07670
07680
07690
07700
07710
07720
07730
07740
07750
0
```



```

C          INPUT SPECTRAL DATA FOR OZONE
C
C      DO 6 J=1, 540, 10
C      K=J+9
C      50 FORMAT(8X, 10(1X,F5.2))
C      6 READ(5,50) (C3(I), I=J, K)
C
C      WRITE(6,69)
C      69 FORMAT(8X,/, 1X, 'SPECTRAL DATA OZONE',/)
C
C      WRITE(6,51)
C      51 FORMAT(7X,/, 1X, 'C301 DATA',/)
C      WRITE(6,50) (C3(I), I=1, 190)
C
C      WRITE(6,52)
C      52 FORMAT(7X,/, 1X, 'C302 DATA',/)
C      WRITE(6,50) (C3(I), I=191, 380)
C
C      WRITE(6,53)
C      53 FORMAT(7X,/, 1X, 'C303 DATA',/)
C      WRITE(6,50) (C3(I), I=381, 540)
C
C      *** INPUT SPECTRAL DATA FOR N2 CONTINUUM
C      READ(5,72) (C4(I), I=1, 5)
C      72 FORMAT(8X, 5(1X,1PE8.2))
C
C      L=0
C      DO 7 J=1, 18
C      L=L+6
C      M=L+6
C      READ(5,55) (C4(I), I=L, M)
C      55 FORMAT(8X, 7(1X,F8.2))
C      L=L+1
C      7 CONTINUE
C
C      READ(5,73) (C4(I), I=132, 133)
C      73 FORMAT(8X, 2(1X,1PE8.2))
C
C      WRITE(6,54)
C      54 FORMAT(7X,/, 1X, 'C4 SPECTRAL DATA- N2 CONTINUUM',/)
C      WRITE(6,72) (C4(I), I=1, 5)
C      WRITE(6,14) (C4(I), I=6, 131)
C      14 FORMAT(1X,7(1X,1PE8.2))
C      WRITE(6,73) (C4(I), I=132, 133)
C
C      *** SPECTRAL DATA H2O CCNTINUUM (4 MICRON REGION DATA)

```

```

LL 01480
LL 01490
LL 01500
LL 01510
LL 01520
LL 01530
LL 01540
LL 01550
LL 01560
LL 01570
LL 01580
LL 01590
LL 01600
LL 01610
LL 01620
LL 01630
LL 01640
LL 01650
LL 01660
LL 01670
LL 01680
LL 01700
LL 01710
LL 01730
LL 01740
LL 01750
LL 01760
LL 01770
LL 01780
LL 01790
LL 01800
LL 01810
LL 01820
LL 01830
LL 01840
LL 01850
LL 01860
LL 01870
LL 01880
LL 01890
LL 01900
LL 01910
LL 01920
LL 01930
LL 01940
LL 01950
LL 01960

```


[illegible]


```

C      READ(5,62) (C703(I),I=43,45)
CC     WRITE(6,66)
C      66 FORMAT(8X,/,1X,'URBAN AEROSOL MODEL',/)
CC     WRITE(6,61) (C703(I),I=1,45)
C
C *** MARITIME AEROSOL MODEL
C
C      DO 67 J=1,42,7
C      K=J+6
C      67 READ(5,59) {C704(I),I=J,K}
C      READ(5,62) {C704(I),I=43,45)
C
C      WRITE(6,68)
C      68 FORMAT(8X,/,1X,'MARITIME AEROSOL MODEL',/)
CC     WRITE(6,61) (C704(I),I=1,45)
C
C *** SPECTRAL DATA AEROSOL ABSORPTION
C *** AVERAGE CONTINENTAL AEROSOL MODEL
C
C      DO 16 J=1,42,7
C      K=J+6
C      16 READ(5,59) {C7A01(I),I=J,K}
C      READ(5,62) {C7A01(I),I=43,45)
C      WRITE(6,17)
C      17 *FORMAT(8X,/,1X,'SPECTRAL DATA AEROSOL ABSORPTION *** AVERAGE
C      *CONTINENTAL AEROSOL MODEL',/)
C      WRITE(6,61) (C7A01(I),I=1,45)
C
C *** RURAL AEROSOL MODEL
C
C      DO 70 J=1,42,7
C      K=J+6
C      70 READ(5,59) {C7A02(I),I=J,K}
C      READ(5,62) {C7A02(I),I=43,45)
C      WRITE(6,71)
C      71 *FORMAT(8X,/,1X,'RURAL AEROSOL MODEL',/)
C      WRITE(6,61) (C7A02(I),I=1,45)
C
C *** URBAN AEROSOL MODEL
C
C      DO 74 J=1,42,7
C      K=J+6
C      74 READ(5,59) {C7A03(I),I=J,K}
C      READ(5,62) {C7A03(I),I=43,45)
C      WRITE(6,75)

```



```

75 FORMAT(8X,/,1X,'URBAN AEROSOL MODEL ',/,)
CC WRITE(6,61) (C1A03(I),I=1,45)
C *** MARITIME AEROSOL MODEL
C
DO 76 J=1,42,7
K=J+6
76 READ(5,59) (C7A04(I),I=J,K)
CC READ(5,62) (C7A04(I),I=43,45)
C WRITE(6,77)
77 FORMAT(8X,/,1X,'MARITIME AEROSOL MODEL',/,)
CC WRITE(6,61) (C1A04(I),I=1,45)
C *** SPECTRAL DATA' OZONE - UV AND VISIBLE
C
REAL(5,72) (C8(I),I=1,5)
L=0
DO 78 J=1,13
L=L+6
M=L+6
REAL(5,55) (C8(I),I=L,M)
L=L+1
78 CONTINUE
79 READ(5,79) (C8(I),I=97,102)
CC FORMAT(8X,6(1X,E8.2))
C
WRITE(6,80)
CC FORMAT(8X,/,1X,'SPECTRAL DATA-- OZONE - UV AND VISIBLE',/,)
C WRITE(6,72) (C8(I),I=1,5)
CC WRITE(6,14) (C8(I),I=6,102)
C *** INPUT PARTIAL AMT OF C2 DATA
C
DO 83 J=951,1570,10
K=J+9
83 READ(5,50) (C2(I),I=J,K)
CC READ(5,50) (C2(I),I=1571,1575)
C
WRITE(6,84)
CC FORMAT(8X,/,1X,'SPECTRAL DATA*** UNIFORMLY MIXED GASES C206 DATA',/,)
C WRITE(6,50) (C2(I),I=951,1140)
CC
C WRITE(6,85)
CC FORMAT(8X,/,1X,'C207 DATA',/,)
CC WRITE(6,50) (C2(I),I=1141,1330)
CC WRITE(6,81)

```

```

LL 02950
LL 02960
LL 02970
LL 02980
LL 02990
LL 03000
LL 03010
LL 03020
LL 03030
LL 03040
LL 03050
LL 03060
LL 03070
LL 03100
LL 03110
LL 03120
LL 03130
LL 03140
LL 03150
LL 03160
LL 03170
LL 03180
LL 03190
LL 03200
LL 03210
LL 03220
LL 03230
LL 03240
LL 03250
LL 03260
LL 03280
LL 03290
LL 03310
LL 03320
LL 03330
LL 03340
LL 03350
LL 03360
LL 03370
LL 03380
LL 03390
LL 03400
LL 03410
LL 03420
LL 03430
LL 03440
LL 03450

```



```

81 FORMAT(8X,1X,'C208 DATA',/)  

CC WRITE(6,50),(C2(I),I=1331,1520)  

CC  

82 FORMAT(8X,1X,'C209 DATA',/)  

CC WRITE(6,50),(C2(I),I=1521,1575)  

CC  

C BEGIN MAIN CODE  

C*****  

CALL ARRAY (P,T,WH,WO,VX,C1,C2,C7,C7A)  

IXY=2  

IP=1  

NL1=NL-1  

DO 208 I TER=1,10000  

IF (IXY.LE.0.OR.IXY.GE.5) GO TO 209  

IF (IXY.EQ.1) GO TO 107  

IF (IXY.EQ.3) GO TO 105  

C  

READ(5,400) MODEL, IAERO, IHAZE, JP, IM, M1, M2, M3, ML, RO, VIS  

IF (MODEL.EQ.1) WRITE(6,410)  

IF (MODEL.EQ.2) WRITE(6,411)  

IF (MODEL.EQ.3) WRITE(6,412)  

IF (MODEL.EQ.4) WRITE(6,413)  

IF (MODEL.EQ.5) WRITE(6,414)  

IF (MODEL.EQ.6) WRITE(6,415)  

IF (M1.NE.0) WRITE(6,444) M1  

IF (M2.NE.0) WRITE(6,445) M2  

IF (M3.NE.0) WRITE(6,446) M3  

IF (IAERO.EQ.1) WRITE(6,447)  

IF (IAERO.EQ.2) WRITE(6,448)  

IF (IAERO.EQ.3) WRITE(6,449)  

IF (IAERO.EQ.4) WRITE(6,450)  

IF (IHAZE.EQ.0) WRITE(6,426)  

IF (IHAZE.EQ.1) AND.CKZERO(VIS) VIS=23.  

IF (IHAZE.EQ.2) AND.CKZERO(VIS) VIS=5.  

IF (.NOT.CKZERO(VIS)) WRITE(6,417) VIS  

IF (VIS.GT.0) AND.VIS.LT.2.0) WRITE(6,442)  

IF (MODEL.EQ.0) M=7  

IF (MODEL.NE.0) M=MODEL  

IF (MODEL.EQ.0) NLP=1  

IF (MODEL.NE.0) AND.MODEL.NE.7) NLP=NL  

IF (MODEL.NE.0) AND.MODEL.NE.7) NLP=MAX0(ML,1)  

IF (MODEL.EQ.7) NLP=MAX0(ML,1) ML,NL  

IF (ML.GT.NL) WRITE(6,451)  

IF (ML.GT.NL) STOP  

C  

DO 101 I = 1,NL  

IF (M.NE.7) AHZ1(I)=HZ1(I)

```



```

101 IF {M.NE.7} AHZ2(I)=HZ2(I)
    IF {M.NE.7} Z(I)=Z0(I)
    CONTINUE
    IF {
        CKZERO(R0)} RE=REARTH(M)
        .NOT.CKZERO(R0)} RE=RO
    IF {M.NE.7.OR.IM.EQ.0} GO TO 104

C**** READ IN RADIOSCNDE (MODEL = 7) OR METEOROLOGICAL (MODEL = 0) DATA
C
100 CONTINUE
DC 103 K = 1,NLP
    IF (MODEL.EQ.0) READ(5,429) Z(K),P(7,K),TMP,DP,RH,WH(7,K),
    IF WO(7,EQ.7) READ(5,429) Z(K),P(7,K),TMP,DP,RH,WH(7,K),
    IF WO(7,K) AHZ1(K)=0.0
    IF (MODEL.EQ.0) AHZ1(K)=0.0
    IF (MODEL.EQ.0) H1=Z(K)
    DO 102 I = 1,NL
        IF (Z(K)-Z0(I)) J=I
        IF (Z(K)-Z0(J)) J=Z0(J)
        FAC = (Z(K)-Z0(J))/Z0(J)
        TT = TMP+2.3
        IF (M1.NE.0) T(7,K)=T(M1,J)*T(7,K)/T(M1,J)**FAC
        IF (.NOT.CKZERO(RH)) TT=273.15/T(7,K)
        IF (.NOT.CKZERO(DP)) TT=273.15/(273.15+DP)
        IF (CKZERO(WH(7,K))) WH(7,K)=EXP(18.9766-14.9595*TT-2.43882
        IF (TT**2)*T
        IF (.NOT.CKZERO(RH)) WH(7,K)=0.01*RH*WH(7,K)
        IF (M2.NE.0) WH(M2,J)*WH(M2,J+1)/WH(M2,J)**FAC
        IF (M3.NE.0) WO(M3,J)*WO(M3,J+1)/WO(M3,J)**FAC
        IF (CKZETC(AHZ1(K))) AHZ2(K)=AHZ1(K)
        IF (.NOT.CKZERO(AHZ1(K))) AHZ2(K)=AHZ1(K)
        IF (CKZETC(AHZ1(K))) AHZ1(K)=AHZ2(K)
        IF (CKZETC(AHZ1(K))) AHZ1(K)=AHZ2(K)
        IF (MODEL.EQ.0) WRITE(6,430) Z(K),P(7,K),TMP,DP,RH,WH(7,K),
        IF WO(7,K)
        IF (MODEL.EQ.7) WRITE(6,429) Z(K),P(7,K),TMP,DP,RH,WH(7,K),
        IF WO(7,K),AHZ1(K)
    CONTINUE

103 CONTINUE
C
104 CCNTINUE
    IF (M1.EQ.0) M1=M
    IF (M2.EQ.0) M2=M
    IF (M3.EQ.0) M3=M
    IF (MODEL.EQ.0) ITYPE=1
    IF (IXY.EQ.4) GO TO 108
    GO TO 107

C
105 CONTINUE

```



```

C
IF (MODEL.EQ.0) GO TO 100
READ(5,406) ITYPE, LEN, H1, H2, ANGLE, RANGE, BETA
X1=RE+H1
IF IND=0
IF (CKZERO (RANGE) .AND. ((ITYPE.EQ.2.AND..NOT.CKZERO (BETA))
. OR. (ITYPE.EQ.3.AND.H2.LT.H1.AND.H2.GT.0.0))) IFIND=1
IF (ITYPE.EQ.1.OR.ITYPE.EQ.3) GO TO 106
ITYPE=2
IF (.NOT.CKZERO (ANGLE) .AND. .NOT.CKZERO (BETA)) H2=
X1*ABS ((SIN (ANGLE*CA)/SIN ((ANGLE-BETA)*CA)))-RE
IF (.NOT.CKZERO (ANGLE) .AND. .NOT.CKZERO (RANGE)) H2=
X1*SQRT (1+((RANGE/X1)**2)*((RANGE/X1)*COS (ANGLE*CA)))-RE
IF (.NOT.CKZERO (BETA) .AND. .NOT.CKZERO (RANGE)) H2=
X1*ABS (CCS (BETA*CA)+SQRT ((RANGE/X1)**2-SIN (BETA*CA)**2))-RE
X2=RE+H2
IF (.NOT.CKZERO (RANGE)) ANGLE=ARCOS (((X2/X1)*(X2/RANGE)-
(X1/RANGE)-((RANGE/X1))/2.)/CA)
IF (.NOT.CKZERO (BETA*CA)) ANGLE=ATAN (X2*SIN (BETA*CA)/(X2*
COS (BETA*CA)-X1))/CA
IF (ANGLE.LT.0.0) ANGLE=ANGLE+180.
IF (CKZERO (RANGE)) RANGE=X1*ABS (SQRT ((X2/X1)**2-SIN (ANGLE*CA)
**2)-COS (ANGLE*CA))
IF (CKZERO (BETA)) BETA=ARSIN ((RANGE/X2)*SIN (ANGLE*CA))/CA
CONTINUE
WRITE(6,428) H1, H2, ANGLE, RANGE, BETA
IF (ITYPE.EQ.1) WRITE(6,407) H1, RANGE
IF (ITYPE.EQ.2) WRITE(6,408) H1, H2, ANGLE
IF (ITYPE.EQ.3) WRITE(6,409) H1, ANGLE
IF (ITYPE.EQ.3) H2=Z(NLP)
CONTINUE
IF (IXY.EQ.3.OR.IXY.EQ.4) GO TO 108
READ(5,405) V1, V2, DV
WL2=10000./V1
WL1=10000./V2
IF (IXY.LE.2) WRITE(6,418) V1, V2, DV, WL1, WL2
WL=SQRT (WL1*WL2)
CO=77.46+0.459/WL**2
CW=43.487-0.3473/WL**2
IF (IXY.EQ.1) GO TO 49
CONTINUE
IF (IFIND.EQ.1) CALL ANGL (H1, H2, ANGLE, BETA, LEN, NLP)
IF (IFIND.EQ.1) GO TO 110
IF (JP.EQ.0) WRITE(6,427)
IF (ITYPE.EQ.1) GO TO 1100
LO 109 K = 1, 10

```

106

C 107

C 108


```

109      VH(K)=0.0
        EETA=0.0
        SR=0.0
C***** NOW DEFINE CONSTANT PRESSURE PATH QUANTITIES EH(1-8)
C
        SPHI=SIN(ANGLE*CA)
        R1=(RE+H1)*SPHI
        IF (H1.LE.Z(NLP)) GO TO 110
        X=(RE+Z(NLP))/(RE+H1)
        IF (SPHI.GT.X) HMIN=R1-RE
        IF (SPHI.GT.X) WRITE(6,433) HMIN
        IF (SPHI.GT.X) GO TO 209
        H1=Z(NLP)
        J1=NLP
        SPHI=SPHI/X
        ANGLE=180.-ARSIN(SPHI)/CA
        CONTINUE
        R1=(RE+H1)*SPHI
        CONTINUE
        DO 112 I = 1,NLP
            PS=P(M,I)/1013.0
            TS=273.15/T(M,I)
            TS1=(296.0/273.15)*TS
            X=PS*TS
            PT=PS*SQRT(TS)
            D=0.1*WH(M2,I)
            PPW=4.56E-6*T(M1,I)*WH(M2,I)
C
C
C
        *** THIS DEFINITION OF HAZE WHEN VIS = 0.0 MAY BE IN ERROR.
C
C
C
        IF (CKZEFO(VIS)) HAZE=0.0
        IF (.NOT.CKZERO(VIS)) HAZE=115.*((AHZ2(I)-AHZ1(I))/VIS+
            AHZ1(I)/5.0-AHZ2(I)/23.0)/18.
        EH(1,I)=L*PT**0.9
        EH(2,I)=X*PT**0.75
        EH(3,I)=46.667*WO(M3,I)*PT**0.4
        EH(4,I)=0.8*PT*X
        EH(5,I)=D*(PPW*EXP(6.08*(TS1-1.0))+0.002*(PS-PPW))
        EH(6,I)=X
        EH(7,I)=3.5336E-4*AMAX1(HAZE,0.0)
        EH(8,I)=46.667*WO(M3,I)
        EH(9,I)=0.0
        EH(10,I)=D*(0.12*PS+0.88*PPW)*EXP(4.56*(TS1-1.0))
        REF=CO*P(M,I)/T(M1,I)-4.56E-6*CW*WH(M2,I)*T(M1,I)}
        IF (I.EQ.NLP) GO TO 111
        PPW=4.56E-6*T(M1,I+1)*WH(M2,I+1)

```



```

111      EH(9,I)=0.5E-6*(REF+CO*P(M,I+1)/T(M,I+1))-PPW*CW)
      IF (IFIND.EQ.0. CR.JP.EQ.0) WRITE(6,434) I,Z(I),
      {EH(K,I),K=1,10),REF
      CONTINUE
      IF (H1.GE.Z(I)) J1=I
      EH(9,I)=EH(9,I)+1.0
      CONTINUE
112      IF (MODEL.NE.0) CALL POINT (H1,YN1,J1,NP1,E,IP)
      TX1=E(9)
      IF (ITYPE.EQ.1) GO TO 47

C***** DOWNWARD TRAJECTORY
      IF (ANGLE.LE.90.) GO TO 19
      K2=0
      IF (NP1.EQ.1) J1=J1-1
      J2=J1+1
      JP1=J1+1
      IF ({H2.GT.Z(J1+1)} .OR. CKZERO(H2-H1)) .OR. (NP1.EQ.1.AND.
      {H2.GE.Z(J1+1)}) GO TO 30
      CALL POINT (H2,YN2,J2,NP2,W,IP)
      TX2=W(9)
      IF (H2.LT.H1) H=H2
      IF (H1.EQ.J2) TX2=TX1+YN2-EH(9,N)
      IF (H2.GT.H1) TX1=TX2
      IF (J1.EQ.J2.AND.H2.LT.H1) YN1=TX2
      A0=(RE+H1)*SEHI*YN1
      IF (H2.GE.H1) YN2=YN1
      DO 31 I=1,J1
      IF (I.NE.J1) HMIN=A0/EH(9,I)-RE
      IF (I.EQ.J1) HMIN=A0/YN1-RE
      IF (HMIN.LE.Z(I+1)) GO TO 32
      CONTINUE
31      X=HMIN
32      IF (HMIN.LE.0.00) GO TO 34

      *** THE USE OF YN BELCW MAY POSSIBLY BE IN ERROR
      SHOULD BE YN1 OR YN2

      CALL POINT (HMIN,YN,JMIN,NP,TX,IP)
      TX3=TX(9)
      IF (J2.EQ.JMIN.OR.J1.EQ.JMIN) TX3=YN2+TX(9)-EH(9,N)
      IF (J1.EQ.JMIN.AND.H2.GE.H1) GO TO 33
      HMIN=A0/TX3-RE
      IF (ABS(X-HMIN).GT.0.0001) GO TO 32
      IF (J1.EQ.JMIN.AND.H2.GE.H1) YN1=TX3
      IF (J2.EQ.JMIN.AND.J1.NE.J2) YN2=TX3
33

```



```

LL 05900
LL 05910
LL 05920
LL 05930
LL 05940
LL 05950
LL 05960
LL 05970
LL 05980
LL 05990
LL 06000
LL 06010
LL 06020
LL 06030
LL 06040
LL 06050
LL 06060
LL 06070
LL 06080
LL 06090
LL 06100
LL 06110
LL 06120
LL 06130
LL 06140
LL 06150
LL 06160
LL 06170
LL 06180
LL 06190
LL 06200
LL 06210
LL 06220
LL 06230
LL 06240
LL 06250
LL 06260
LL 06270
LL 06280
LL 06290
LL 06300
LL 06310
LL 06320
LL 06330
LL 06340
LL 06350
LL 06360

```

```

IF (H2.GE.H1) TX2=TX3
IF (H2.GE.H1) J2=JMIN
IF (H2.GE.H1.OR.H2.LT.HMIN) H=HMIN
WRITE(6,436) HMIN
IF (H2.LT.HMIN) WRITE(6,440) HMIN
GO TO 35

```

C 34

```

WRITE(6,436) HMIN
IF (H2.LT.H1) GO TO 35
IF (ITYPE.EQ.3.OR.H2.GE.H1) WRITE(6,437)
ITYPE=2
TX2=EH(9,1)
JMIN=0
J2=1
H2=0.0
H=0.0

```

C ***** NOW DEFINE VERTICAL PATH QUANTITIES VH(1-8)

```

C 35 IF (JP.EQ.0) WRITE(6,420)
DO 135 I=1,1000
IF (K2.EQ.0) REF=YN1
IF (K2.EQ.1) REF=YN2
X1=H1
J=JP1+1
CONTINUE
J=J-1
X2=Z(J)

```

38

```

IF (J.EQ.0) J2=AND(K2.EQ.0) X2=H
IF (J.EQ.JMIN.AND.K2.EQ.1) X2=HMIN
HM=(RE+X1)*SPHI-RE
IF (HM.GT.Z(J).AND.HM.GT.X2) X2=HM
RX=(RE+X1)/(RE+X2)
DS=X1-X2
ALP=90.0
THET=ARCSIN(SPHI)/CA
SALP=RX*SPHI
IF (ABS(X2-HM).GT.1.E-5) ALP=ARSIN(SALP)/CA
BET=ALP-THET
IF (SPHI.GT.1.E-10) DS=(RE+X2)*SIN(BET*CA)/SPHI
THETA=180.-THET
BETA=BETA+BET
PSI=BETA-ALP-ANGLE+180.
SR=SR+DS
DO 39 K=1,10
AJ=EH(K,J)
BJ=EH(K,J+1)

```



```

IF (J.EQ.J1) BJ=E(K)
IF (J.EQ.J2) AND.H2.LT.H1.AND.H2.GT.0.0) AJ=W(K)
IF (J.EQ.JMIN.AND.H2.GE.H1) AJ=TX(K)
IF (J.EQ.JMIN.AND.ABS(H2-H1).LT.1.E-5) AJ=TX(K)
IF (K2.NE.0.AND.J.EQ.J2) BJ=W(K)
IF (K2.NE.0.AND.J.EQ.JMIN) AJ=TX(K)
IF (CKZERO(AJ).OR.CKZERO(BJ)) EV=0.0
IF (CKZERO(AJ-BJ)) EV=DS*AJ
IF (.NOT.CKZERO(AJ).AND..NOT.CKZERO(BJ).AND.
.NOT.CKZERO(AJ-BJ)) EV=DS*(AJ-BJ)/ALOG(AJ/BJ)
VH(K)=VH(K)+EV
CONTINUE
(JP.EQ.0) WRITE(6,435) J,X1,(VH(L),L=1,8),PSI,ALP,
BETA,THETA,SR
IF (J.EQ.J2.AND.H2.GE.H1) GO TO 45
IF (J.EQ.JMIN.AND.K2.EQ.1) GO TO 43
IF (J.NE.1) RN=REF/TH2
IF (J.EQ.J2+1) RN=REF/TH2
IF (J.EQ.J2.AND.K2.EQ.0) RN=REF/YN2
IF (J.EQ.(JMIN+1).AND.K2.EQ.1) RN=REF/TH3
IF (SALP.GE.RN) RN=1.0
SPHI=SALP*RN
REF=EH(9,J)
IF (J.EQ.J2+1.AND.K2.EQ.0) REF=TH2
X1=X2
IF (J.NE.1.AND.(J.NE.J2.OR.K2.NE.0)) GO TO 38
IF (HMIN.LE.0.0) GO TO 47
IF (LEN.EQ.0) WRITE(6,438)
IF (LEN.EQ.0) GO TO 47
WRITE(6,439)
K2=1
IF (ABS(X1-HMIN).LE.0.001) GO TO 47
H=HMIN
JP1=J2+1
IF (NP2.EQ.1) JP1=JP1-1
E=BETA
PH=180.-ARSIN(SPHI)/CA
TS=SR
PS=PSI
DO 42 K=1,10
E(K)=VH(K)
CONTINUE
BETA=2.*BETA-B
PSI=2.*PSI-PS
SR=2.*SR-TS
C*** LCNG PATH TAKEN

```

42
135
43


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C
44      PHI=PH
      DO 44 K = 1,10
      VH (K) = 2.*VH(K) - E(K)
      GO TO 47
C
45      CCNTINUE
      DO 46 K = 1,10
      VH (K) = 2.*VH(K)
      EETA = 2.*BETA
      SR = 2.*SR
      IF (CKZERO (H2-H1)) GO TO 47
      RN = TX1/YN1
      SPHI = SIN(ANGLE*CA)
      IF (SPHI.LT.FN) SPHI = SPHI/RN
C
C****
C      UPWARD TRAJECTORY
      IF (ANGLE.GT.90..AND.NP1.GT.0) J1=J1+1
      IF (ITYPE.EQ.3) J2=NLP
      IF (ITYPE.EQ.2) CALL POINT(H2,YN2,J2,NP,TX,IP)
      IF (ITYPE.EQ.2..AND.NP.EQ.1) J2=J2-1
      EH (10,J1) = E(10)
      DO 21 K = 1,E
      IF (ITYPE.EQ.3) EH(K,J1) = E(K)
      IF (ITYPE.EQ.2) EH(K,J2+1) = TX(K)
      CONTINUE
      IF (ITYPE.EQ.2) EH (10,J2+1) = TX (10)
      IF (J1.EQ.J2) TX1 = TX1+YN2-EH (9,J1)
C
C****
C      NOW DEFINE VERTICAL PATH QUANTITIES VH(1-8)
      IF (JP.EQ.0) WRITE (6,420)
      X1=H1
      DO 25 I = J1,J2
      X2 = Z(I+1)
      IF (I.EQ.J2) X2=H2
      DZ = X2-X1
      IF (I.EQ.NLP) DZ = Z(I) - Z(I-1)
      RX = (RE+X1)/(RE+X2)
      THETA = ARSIN(SPHI)/CA
      PHI = ARSIN(SPHI*RX)/CA
      BET = THETA-PHI
      SALP = RX*SPHI
      IF (SPHI.GT.1.E-10) DZ = (RE+X2)*SIN(BET*CA)/SPHI
      BETA = BET
      PSI = BETA+PHI-ANGLE

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LL 06840
LL 06850
LL 06860
LL 06870
LL 06880
LL 06890
LL 06900
LL 06910
LL 06920
LL 06930
LL 06940
LL 06950
LL 06960
LL 06970
LL 06980
LL 06990
LL 07000
LL 07010
LL 07020
LL 07030
LL 07040
LL 07050
LL 07060
LL 07070
LL 07080
LL 07090
LL 07100
LL 07110
LL 07120
LL 07130
LL 07140
LL 07150
LL 07160
LL 07170
LL 07180
LL 07190
LL 07200
LL 07210
LL 07220
LL 07230
LL 07240
LL 07250
LL 07260
LL 07270
LL 07280
LL 07290
LL 07300

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PHI=180.-PHI
SR=SR+DZ
IO=MAXO(MINO(I,NLP-1),1)
DO 24 K=1,10
  IF (CKZERO(EH(K,IO)).OR. CKZERO(EH(K,IO+1)).OR.
    EV=DZ*AMIN1(EH(K,IO),EH(K,IO+1))
  IF (.NOT. CKZERO(EH(K,IO)).AND..NOT. CKZERO(EH(K,IO+1))
    .AND..NOT. CKZERO(EH(K,IO)-EH(K,IO+1)).AND. I.NE. NLP)
    EV=DZ*(EH(K,IO)-EH(K,IO+1))/ALOG(EH(K,IO)/
    EH(K,IO+1))
  IF (.NOT. CKZERO(EH(K,IO)).AND..NOT. CKZERO(EH(K,IO+1))
    .AND..NOT. CKZERO(EH(K,IO)-EH(K,IO+1)).AND. I.EQ. NLP)
    EV=DZ*(EH(K,IO)-EH(K,IO+1))/ALOG(EH(K,IO)/EH(K,IO+1))
  VH(K)=VH(K)+EV
CONTINUE
IF (JP.EQ.0) WRITE(6,435) I,X1,(VH(L),L=1,8),PSI,PHI,BETA,
  THETA,SR
  IF (I.EQ.NLP) GO TO 25
  IF (I.EQ.J2-1) EH(9,I+1)=YN2
  IF (I.EQ.J1) EH(9,I)=TX1
  RN=EH(9,I+1)/EH(9,I)
  SPHI=SPHI*RX/RN
  IF (SALP-GE.RN) SPHI=SALP
  X1=X2
CONTINUE
CONTINUE
IF (ITYPE.NE.1) WRITE(6,443) HM
DO 48 K=1,10
  IF (ITYPE.EQ.1.AND.MODEL.NE.0) W(K)=RANGE*E(K)
  IF (ITYPE.EQ.1.AND.MODEL.EQ.0) W(K)=RANGE*EH(K,1)
  IF (ITYPE.NE.1) W(K)=VH(K)
CONTINUE
WRITE(6,419) (W(I),I=1,8),W(10)
WRITE(6,421)
C**** BEGINNING OF TRANSMITTANCE CALCULATIONS
C
IV1=MAXO(5*IFIX(V1/5.0),350)
IV2=MINO(5*IFIX(V2/5.0+6.99),50000)
IV=AMAX1(DV,5.0)
IDV=IFIX(DV)
SUM=0.0
DO 206 IV=IV1,IV2,IDV
  IF (IV-GE.350.AND. IV.LT. 9875) I={IV-350}/5+1
  IF (IV-GE. 9875.AND. IV.LT.12800) I={IV-9875}/5+1771
  IF (IV-GE.12800.AND. IV.LT.13400) I={IV-12800}/5+2491

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IF (IV.GE.13400.AND.IV.LE.14500) /5+ 2356
IF (IV.GE.14500.AND.IV.LE.50000) /5+ 2831
IF (IV.GE.500.AND.IV.LT.8060) /5+ 1
IF (IV.GT.12970.AND.IV.LT.13190) /5+ 1520
K= (IV-575)/5+1
IF ((IV.GE.350.AND.IV.LT.12800).OR.
((IV.GE.13400.AND.IV.LE.14500)
WS1=ALOG10(A MAX1(W(1),GE.1.0E-20)
)+C1(I)
IF (IV.IT.350.OR.IV.GE.12800).AND.
WS1=FW(1) -1.0
IF (IV.LT.13400.OR.IV.GT.14500).OR.
((IV.GE.500.AND.IV.LT.8060)
WS2=ALOG10(A MAX1(W(2),GE.1.0E-20)
)+C2(J)
IF (IV.LT.500.OR.IV.GE.8060).AND.
WS2=FW(1) -1.0
IF (IV.GE.575.AND.IV.LE.3270).OR.
WS3=ALOG10(A MAX1(W(3),GE.1.0E-20)
)+C3(K)
IF (IV.LT.575.OR.IV.GT.3270) WS3=FO(1) -1.0
NS1=0
NS2=0
NS3=0
DO 202 L = 1,67
IF (WS1.GE.FW(L)) NS1=L
IF (WS2.GE.FW(L)) NS2=L
IF (WS3.GE.FW(L)) NS3=L
CONTINUE
202
C***** WATER VAPOR
C
IF (NS1.EQ.0) TX(1)=1.0
IF (NS1.GT.0.AND.NS1.LT.67) TX(1)=TR(NS1+1)+
TR(NS1)-TR(NS1+1))* (FW(NS1+1) -FW(NS1))
IF (NS1.EQ.67) TX(1)=0.0
C***** UNIFORMLY MIXED GASES
C
IF (NS2.EQ.0) TX(2)=1.0
IF (NS2.GT.0.AND.NS2.LT.67) TX(2)=TR(NS2+1)+
TR(NS2)-TR(NS2+1))* (FW(NS2+1) -FW(NS2))
IF (NS2.EQ.67) TX(2)=0.0
C***** OZCNE
C
IF (NS3.EQ.0) TX(3)=1.0
IF (NS3.GT.0.AND.NS3.LT.67) TX(3)=TR(NS3+1)+
TR(NS3)-TR(NS3+1))* (FO(NS3+1) -FO(NS3))
IF (NS3.EQ.67) TX(3)=0.0

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C***** NITROGEN CONTINUUM
K=(IV-2080)/5+1
IF {IV.LT.2080.OR.IV.GE.2740} TX(4)=0.0
IF {IV.GE.2080.AND.IV.LT.2740} TX(4)=C4(K)*W(4)
LL 08250
LL 08260
LL 08280
LL 08290
LL 08300
LL 08310
LL 08320
LL 08340
LL 08350
LL 08360
LL 08370
LL 08380
LL 08400
LL 08410
LL 08420
LL 08430
LL 08450
LL 08460
LL 08470
LL 08480
LL 08500
LL 08510
LL 08520
LL 08530
LL 08540
LL 08560
LL 08570
LL 08580
LL 08590
LL 08600
LL 08610
LL 08620
LL 08630
LL 08640
LL 08650
LL 08660
LL 08670
LL 08680
LL 08690
LL 08700
LL 08710
LL 08720
LL 08730
LL 08740
LL 08750
LL 08770
LL 08780

C***** WATER VAPOR CONTINUUM
XI=FLOAT(IV-2350)/50.0
NH=IFIX(XI)
TX(5)=0.0
LL 08250
LL 08260
LL 08280
LL 08290
LL 08300
LL 08310
LL 08320
LL 08340
LL 08350
LL 08360
LL 08370
LL 08380
LL 08400
LL 08410
LL 08420
LL 08430
LL 08450
LL 08460
LL 08470
LL 08480
LL 08500
LL 08510
LL 08520
LL 08530
LL 08540
LL 08560
LL 08570
LL 08580
LL 08590
LL 08600
LL 08610
LL 08620
LL 08630
LL 08640
LL 08650
LL 08660
LL 08670
LL 08680
LL 08690
LL 08700
LL 08710
LL 08720
LL 08730
LL 08740
LL 08750
LL 08770
LL 08780

C*****
10 MICRON REGION
IF (IV.GE.670.AND.IV.LE.1350) TX(5)=(4.18+5578.0*
EXP(-7.87E-3*FLOAT(IV)))*W(5)
LL 08250
LL 08260
LL 08280
LL 08290
LL 08300
LL 08310
LL 08320
LL 08340
LL 08350
LL 08360
LL 08370
LL 08380
LL 08400
LL 08410
LL 08420
LL 08430
LL 08450
LL 08460
LL 08470
LL 08480
LL 08500
LL 08510
LL 08520
LL 08530
LL 08540
LL 08560
LL 08570
LL 08580
LL 08590
LL 08600
LL 08610
LL 08620
LL 08630
LL 08640
LL 08650
LL 08660
LL 08670
LL 08680
LL 08690
LL 08700
LL 08710
LL 08720
LL 08730
LL 08740
LL 08750
LL 08770
LL 08780

C*****
4 MICRON REGION
IF (IV.GE.2350.AND.IV.LE.3000) TX(5)=(C5(NH)+ (XI-FLOAT(NH))
*(C5(NH+1)-C5(NH)))*W(10)
LL 08250
LL 08260
LL 08280
LL 08290
LL 08300
LL 08310
LL 08320
LL 08340
LL 08350
LL 08360
LL 08370
LL 08380
LL 08400
LL 08410
LL 08420
LL 08430
LL 08450
LL 08460
LL 08470
LL 08480
LL 08500
LL 08510
LL 08520
LL 08530
LL 08540
LL 08560
LL 08570
LL 08580
LL 08590
LL 08600
LL 08610
LL 08620
LL 08630
LL 08640
LL 08650
LL 08660
LL 08670
LL 08680
LL 08690
LL 08700
LL 08710
LL 08720
LL 08730
LL 08740
LL 08750
LL 08770
LL 08780

C***** MOLECULAR SCATTERING
IF (IV.LT.2740) TX(6)=0.0
IF {IV.GE.2740.AND.IV.LE.50000}
TX(6)=9.807E-20*(FLOAT(IV))*4.0117)*W(6)
LL 08250
LL 08260
LL 08280
LL 08290
LL 08300
LL 08310
LL 08320
LL 08340
LL 08350
LL 08360
LL 08370
LL 08380
LL 08400
LL 08410
LL 08420
LL 08430
LL 08450
LL 08460
LL 08470
LL 08480
LL 08500
LL 08510
LL 08520
LL 08530
LL 08540
LL 08560
LL 08570
LL 08580
LL 08590
LL 08600
LL 08610
LL 08620
LL 08630
LL 08640
LL 08650
LL 08660
LL 08670
LL 08680
LL 08690
LL 08700
LL 08710
LL 08720
LL 08730
LL 08740
LL 08750
LL 08770
LL 08780

C***** AEROSOL EXTINCTION
WL=10000./FLOAT(IV)
XX=0.0
YY=0.0
TX(7)=0.0
TX(10)=0.0
IF {HAZE.EQ.0} GO TO 204
NS=0
DO 203 L=1,44
IF (WL.GE.VX(IAERO,L)) NS=L
IF (NS.GT.0.AND.NS.LT.44) XX=C7(IAERO,NS+1)*
(C7(IAERO,NS)-C7(IAERO,NS+1))-VX(IAERO,NS)
IF {VX(IAERO,NS+1)-VX(IAERO,NS)}
NS.GT.0.AND.NS.LT.44) YY=C7A(IAERO,NS+1)+
(C7A(IAERO,NS)-C7A(IAERO,NS+1))-VX(IAERO,NS)
CONTINUE
TX(7)=XX*W(7)
TX(10)=YY*W(7)
LL 08250
LL 08260
LL 08280
LL 08290
LL 08300
LL 08310
LL 08320
LL 08340
LL 08350
LL 08360
LL 08370
LL 08380
LL 08400
LL 08410
LL 08420
LL 08430
LL 08450
LL 08460
LL 08470
LL 08480
LL 08500
LL 08510
LL 08520
LL 08530
LL 08540
LL 08560
LL 08570
LL 08580
LL 08590
LL 08600
LL 08610
LL 08620
LL 08630
LL 08640
LL 08650
LL 08660
LL 08670
LL 08680
LL 08690
LL 08700
LL 08710
LL 08720
LL 08730
LL 08740
LL 08750
LL 08770
LL 08780

C***** UV OZONE
IF {IV.GE.13000.AND.IV.LE.23400} XI=FLOAT(IV-13000)/200.+1.
IF {IV.GE.27500.AND.IV.LE.50000} XI=FLOAT(IV-27500)/500.+57.
LL 08250
LL 08260
LL 08280
LL 08290
LL 08300
LL 08310
LL 08320
LL 08340
LL 08350
LL 08360
LL 08370
LL 08380
LL 08400
LL 08410
LL 08420
LL 08430
LL 08450
LL 08460
LL 08470
LL 08480
LL 08500
LL 08510
LL 08520
LL 08530
LL 08540
LL 08560
LL 08570
LL 08580
LL 08590
LL 08600
LL 08610
LL 08620
LL 08630
LL 08640
LL 08650
LL 08660
LL 08670
LL 08680
LL 08690
LL 08700
LL 08710
LL 08720
LL 08730
LL 08740
LL 08750
LL 08770
LL 08780

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      *
      *
      *
C
      N=IF IX(XI)+1
      IF ((IV.GE.13000.AND.IV.LE.23400).OR.
        {IV.GE.27500.AND.IV.LE.50000})
        TX(8)=W(8)*(C8(N)+(XI-FLOAT(N))*C8(N-1))
        AND.
        {IV.LT.13000.OR.IV.GT.23400}.
        TX(8)=0.0
      IF ((IV.LT.27500.OR.IV.GT.50000))
        TX(9)=0
        IF (IV.GE.2080.AND.IV.LT.2740) TX(9)=TX(9)+TX(4)
        IF (IV.GT.670.AND.IV.LT.3000) TX(9)=TX(9)+TX(5)
        IF (IV.GE.2740.AND.IV.LT.50000) TX(9)=TX(9)+TX(6)
        TX(9)=TX(9)+TX(7)
        IF ((IV.GE.13000.AND.IV.LE.23400).OR.
          {IV.GE.27500.AND.IV.LE.50000}) TX(9)=TX(9)+TX(8)
        DO 205 L=4,10
          TX(L)=EXP(-TX(L))
          TX(10)=1.0-TX(10)
          TX(9)=TX(1)*TX(2)*TX(3)*TX(9)
          IF (IV.GE.13000.AND.IV.LE.50000) TX(3)=TX(8)
          IF (JP.EQ.3) TX(9)=TX(7)
          AB=1.0-TX(9)
          IF (IV.EQ.IV1.OR.IV.EQ.IV2) AB=0.5*AB
          SUM=SUM+AB*FLOAT(IDV)
          IF (JP.EQ.0.AND.IABS(MOD(IV-IV1,50*IDV)).EQ.0) WRITE(6,422)
          IF (JP.EQ.0) WRITE(6,423) IV,WL,TX(9),(TX(L),L=1,7),TX(10),
            SUM
          CONTINUE
          AB=1.-SUM/FLOAT(IV2-IV1)
          WRITE(6,424) IV1,IV2,SUM,AB
          READ(5,400) IXY
          CONTINUE
          CONTINUE
          STCF
        C
        400 FORMAT(9I3,3X,2F10.3)
        405 FORMAT(3F10.3)
        406 FORMAT(2I3,4X,5F10.3)
        407 FORMAT(/10X,29H HORIZONTAL PATH, ALTITUDE = , F7.3,13H KM, RANGE
          * F7.3,3H KM)
        408 FORMAT(/10X,51H SLANT PATH BETWEEN ALTITUDES H1 AND H2 WHERE H1
          * F7.3,9H KM,H2 = ,F7.3,20H KM,ZENITH ANGLE = ,F7.3,8H DEGREES)
        409 FORMAT(/10X,40H SLANT PATH TO SPACE FROM ALTITUDE H1 = ,F7.3,19H
          * KM,ZENITH ANGLE = ,F7.3,8H DEGREES)
        410 FORMAT(.1'/10X,41H TROPICAL (15 DEG. LAT.) MODEL ATMOSPHERE)
        411 FORMAT(.1'/10X,51H MIDLATITUDE (45 DEG. LAT.) SUMMER MODEL ATMOSP
          * FERE)
        412 FORMAT(.1'/10X,51H MIDLATITUDE (45 DEG. LAT.) WINTER MODEL ATMOSP

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LL 08790
LL 08800
LL 08810
LL 08820
LL 08830
LL 08840
LL 08850
LL 08860
LL 08870
LL 08880
LL 08890
LL 08900
LL 08910
LL 08920
LL 08930
LL 08940
LL 08950
LL 08960
LL 08970
LL 08980
LL 08990
LL 09000
LL 09010
LL 09020
LL 09030
LL 09040
LL 09050
LL 09060
LL 09070
LL 09080
LL 09090
LL 09100
LL 09110
LL 09120
LL 09130
LL 09140
LL 09150
LL 09160
LL 09170
LL 09180
LL 09190
LL 09200
LL 09210
LL 09220
LL 09230
LL 09240
LL 09250

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* C7A04(45), C8(102), VX01(45), VX02(45), VX03(45), VX04(45),
* EH(10,34), M, M1, M2, M3, RE, CW, CO, PI, CA, REARTH(7), Z(34)
01280 LL
01390 LL
10240 LL
10250 LL

* DIMENSION
    TX(10), P(7,34), T(7,34), WH(7,34), WO(7,34), VX(4,45)
    C7(4,45), C7A(4,45), C1(2580), C2(1575)
10260 LL
10270 LL
10280 LL
10290 LL
10300 LL
10310 LL
10320 LL
10330 LL
10340 LL
10350 LL
10360 LL
10370 LL
10380 LL
10390 LL
10400 LL
10410 LL
10420 LL
10430 LL
10440 LL
10450 LL
10460 LL
10470 LL
10480 LL
10490 LL
10500 LL
10510 LL
10520 LL
10530 LL
10540 LL
10550 LL
10560 LL
10570 LL
10580 LL
10590 LL
10600 LL
10610 LL
10620 LL
10630 LL
10640 LL
10650 LL
10660 LL

* LOGICAL
    CKZERO
10260 LL
10270 LL
10280 LL
10290 LL
10300 LL
10310 LL
10320 LL
10330 LL
10340 LL
10350 LL
10360 LL
10370 LL
10380 LL
10390 LL
10400 LL
10410 LL
10420 LL
10430 LL
10440 LL
10450 LL
10460 LL
10470 LL
10480 LL
10490 LL
10500 LL
10510 LL
10520 LL
10530 LL
10540 LL
10550 LL
10560 LL
10570 LL
10580 LL
10590 LL
10600 LL
10610 LL
10620 LL
10630 LL
10640 LL
10650 LL
10660 LL

REF(X,Y,Z)=CO*X/Y-4.56E-6*Z*Y*CW
CKZERO(X)=ABS(X).LT.1.E-20
10260 LL
10270 LL
10280 LL
10290 LL
10300 LL
10310 LL
10320 LL
10330 LL
10340 LL
10350 LL
10360 LL
10370 LL
10380 LL
10390 LL
10400 LL
10410 LL
10420 LL
10430 LL
10440 LL
10450 LL
10460 LL
10470 LL
10480 LL
10490 LL
10500 LL
10510 LL
10520 LL
10530 LL
10540 LL
10550 LL
10560 LL
10570 LL
10580 LL
10590 LL
10600 LL
10610 LL
10620 LL
10630 LL
10640 LL
10650 LL
10660 LL

CALL ARRAY(P,T,WH,W0,VX,C1,C2,C7,C7A)
N=0
X=AMAX1(X,0.0)
N1=NL-1
DO 101 I=1,N1
    IF (X-GT.Z(I)) N=I
    IF (.NOT. CKZERO(X-Z(N+1))) NP=0
    IF (N.EQ.0.OR. NP.EQ.1) GO TO 102
    FAC=AMIN1((X-Z(N))/Z(N+1), NP)
    FX1=F(M,N)*P(M,N+1)/F(M,N)**FAC
    TX1=T(M,N)*T(M,N+1)/T(M,N)**FAC
    WX1=WH(M,N)*WH(M,N+1)/WH(M,N)**FAC
    YN=(REF(P,M,N)-REF(P,M,N+1))+REF(PX1,TX1,WX1))/2.
    GO TO 103
101
CONTINUE
TX(9)=(EH(9,N+1)-1.)*1.E+06
IF (N.EQ.0) YN=0.0
IF (N.NE.0) YN=(EH(9,N)-1.)*1.E+06
CONTINUE
102
IF (IP.EQ.0) GO TO 105
DO 104 K=1,10
    IF (N.EQ.0.OR. CKZERO(EH(K,N))) .AND. K.NE.9) TX(K)=0.0
    IF (N.NE.0 .AND. .NOT. CKZERO(EH(K,N))) .AND. K.NE.9) TX(K)=
    * EH(K,N)*(EH(K,N+1)/EH(K,N))*FAC
    CONTINUE
    WRITE(6,1) X,N,NP,TX(9),YN,(TX(K),K=1,8)
    CCNTINUE
    TX(5)=1.+TX(9)*1.E-06
    YN=1.+YN*1.E-06
104
RETURN
FORMAT(10X,'FROM POINT - HEIGHT =',F10.4,9H KM, N =,I3,7H,
* =,I2,35H, REFRACTIVITY ABOVE AND BELOW X =,2(1PE10.3)/10X,
* 40H EQUIVALENT ABSORBER AMOUNTS PER KM AT X//20X,8(1PE10.3))
NP

```



```

TN=THET
TM=TN-0.5*CA
DO 101 ITER = 1,10
  ANGLE=0.0
  FB1=0.0
  FB2=0.0
  FB3=0.0
  IF (BETA.LE.0.0) GO TO 2
  IF (2*THET-PI.GT.1.E-8) GO TO 9
  IF (IP.EQ.100) GO TO 6
  XMIN=X2*COS(ETA)-RE
  IF (XMIN.LT.H1) GO TO 8
  IF (XMIN.GE.H1) GO TO 4
  HM1=H2
  H2=H1
  H1=HM1
  ANGLE=0.5*PI
  THET=ANGLE
  SPHI=1.0
  ANG=ANGLE/CA
  IP=100
  CALL POINT (H1,YN,J1,NE,TX,IP)
  TX1=TX(9)
  CALL POINT (H2,YN,J2,NE,TX,IP)
  IF (NP.EQ.1) J2=J2-1
  IF (J1.EQ.J2) TX1=TX1+YN-EH(9,J1)
  CCNT=CCNT+1
  X1=RE+H1
  FB1=-TAN(THET)
  DO 7 J = J1,J2
    IF (J.NE.J2) X2=RE+Z(J+1)
    IF (J.EQ.J2) X2=RE+H2
    SALP=X1*SPhi/X2
    ALP=AR SIN(SALP)
    RN=EH(9,J+1)/EH(9,J)
    IF (J+1).EQ.J2) RN=YN/EH(9,J)
    IF (J.EQ.J1) RN=EH(9,J+1)/TX1
    IF (J+1).EQ.J2) RN=YN/TX1
    FB1=FB1+TAN(THET)-TAN(ALP)
    TH1=THET/CA
    C=ALP/CA
    IF (CKZEFO(X2-(RE+H2))) C=PI-ALP

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11130 LL
11140 LL
11150 LL
11160 LL
11170 LL
11180 LL
11190 LL
11200 LL
11210 LL
11220 LL
11230 LL
11240 LL
11250 LL
11260 LL
11270 LL
11280 LL
11290 LL
11300 LL
11310 LL
11320 LL
11330 LL
11340 LL
11350 LL
11360 LL
11370 LL
11380 LL
11390 LL
11400 LL
11410 LL
11420 LL
11430 LL
11440 LL
11450 LL
11460 LL
11470 LL
11480 LL
11490 LL
11500 LL
11510 LL
11520 LL
11530 LL
11540 LL
11550 LL
11560 LL
11570 LL
11580 LL
11590 LL

```

2
3
4
5
6


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IF (SALP-GE.RN) RN=1.
SPHI=SALF/RN
THET=ARSIN(SPHI)
X1=X2
CONTINUE
IF (BETA.LE.0.0) THET=C
IF (BETA.LE.0.0) GO TO 28
GO TO 26
CONTINUE
TANG=-TANG
ANGLE=PI-ANGLE
TN=ANGLE
ANG=ANGLE/CA
IF (H1.LE.0.0) GO TO 3
CONTINUE
IP=101
CALL POINT (H1,YN1,J1,NP1,TX,IP)
TX1=TX(9)
IF (NP1.EQ.1) J1=J1-1
J2=ML
IF (H2-GE.H1) GO TO 13
CALL POINT (H2,YN2,J2,NP2,TX,IP)
TX2=TX(9)
IF (J1.EQ.J2) TX2=YN1+TX(9) -EH(9,J1)
J2F=J2-1
DO 102 J = J1,J2P
X1=RE+Z(J+1)
X2=RE+Z(J)
IF (J.EQ.J1) X1=RE+H1
IF (J.EQ.J2) X2=RE+H2
SALP=X1*SPHI/X2
HMIN=X1*SPHI-RE
IF (SALP.LE.1.0) GO TO 11
SALP=SPHI
IF (HMIN.GT.H2) GO TO 18
ALP=ARSIN(SALP)
THET=ARSIN(SPHI)
BET=ALP-THET
BET1=BET1+BET
PB=TAN(ALP)
IF (J.NE.J1) PB=PB-TAN(THET)
PB1=PB1+PB
TH1=THET/CA
BE=BET/CA
AL=ALP/CA
IF (CKZERO(X2-(RE+H2))) C=PI-ALP
REF=EH(9,J)

```

7

8

9

11

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LL 11600
LL 11610
LL 11620
LL 11630
LL 11640
LL 11650
LL 11660
LL 11670
LL 11680
LL 11690
LL 11700
LL 11710
LL 11720
LL 11730
LL 11740
LL 11750
LL 11760
LL 11770
LL 11780
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LL 11800
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LL 11890
LL 11900
LL 11910
LL 11920
LL 11930
LL 11940
LL 11950
LL 11960
LL 11970
LL 11980
LL 11990
LL 12000
LL 12010
LL 12020
LL 12030
LL 12040
LL 12050
LL 12060

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12070 LL
12080 LL
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12100 LL
12110 LL
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12220 LL
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12240 LL
12250 LL
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12300 LL
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12370 LL
12380 LL
12390 LL
12400 LL
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12460 LL
12470 LL
12480 LL
12490 LL
12500 LL
12510 LL
12520 LL
12530 LL

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102 IF (J.EQ.J1) REF=YN1
112 IF (J.EQ.J2) REF=TX2
113 IF (J.EQ.J1) GO TO 12
114 RN=EH(9,J)/EH(9,J-1)
115 IF (J.EQ.J1) RN=YN1/EH(9,J-1)
116 IF (J.EQ.J2+1) RN=REF/TX2
117 IF (J.EQ.J2) RN=REF/YN2
118 IF (SALP.GE.RN) RN=1.
119 SPHI=SALP*RN
120 IF (Z(J).LE.H2) GO TO 12
121 CONTINUE
122 X1=X2
123 IF (ABS (Z (J) -H2) .GE. 1.0E-10.OR.J.EQ.1) GO TO 14
124 J=J-1
125 X1=RE+Z (J+1)
126 IF (J.EQ.J1) X1=RE+H1
127 IF (J.EQ.J2.AND.J.NE.J1) X1=RE+H2
128 X2=RE+Z (J)
129 HMIN=X1*SPHI-RE
130 IF (HMIN.LE.0.0) B1=BET1
131 IF (HMIN.LE.0.0) LEN=0
132 IF (HMIN.LE.0.0) FBT=FBT1
133 IF (HMIN.LE.0.0) GO TO 26
134 IF (Z(J).LT.HMIN) GO TO 18
135 REF=EH(9,J)
136 IF (J.EQ.J2) REF=YN
137 SALP=X1*SPHI/X2
138 THET=ARCSIN (SALP)
139 FET=ALP-THET
140 FB=TAN (ALP)-TAN (THET)
141 FBT2=FBT2+FE
142 BET2=BET1+FBT
143 BMIN=BET1+BET2
144 AL=ALP/CA
145 TH1=THET/CA
146 RN=REF/EH(9,J-1) RN=1.0
147 IF (SALP.GE.RN)
148 SPHI=SALP*RN
149 GO TO 13
150 TX3=YN1+TX (9)-EH(9,J1)
151 YN1=TX3
152 IF (ABS (H2-Z (J+1)) .LE.1.0E-5) YN1=TX (9)
153 IF (ABS (H1-Z (J+1)) .LE.1.0E-5) YN1=TX (9)
154 EN=1.0
155 GO TO 19
156 CALL POINT (HMIN,YN,J2,NP,TX,IP)
157
158

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IP=102 TX3=TX (9) J1.AND.H2.GE.H1) GO TO 17
IF (J.EQ.J1.OR.J.EQ.J2) TX3=YN2+TX (9)-EH (9,J)
IF (HMIN.GT.H2) TX3=TX (9)
IF (J.EQ.J1.AND.HMIN.GT.H2) GO TO 17
RN=REF/TX3
IF (SALP.GE.FN) RN=1.
SPHI=SALP*RN
X=X1*SPHI-RF
DIF=ABS (HMIN-X)
HMIN=X
IF (DIF.GT. 1.0E-5) GO TO 18
X2=RE+HMIN
THET=AROSIN(SPHI) FBT3=-TAN(THET)
IF (CKZERO (RN)) GO TO 20
IF (CKZERO (RN)) GO TO 20
DNX=((TX3-1.0)*A LOG ((TX3-1.0)/(REF-1.0))/(X2-X1)
FBT3=-TAN(THET)*(1.0-1.0/(1.0+TX3/(X2*BNX)))
BET=0.5*PI-THET
BET2=BET+BET2
BMIN=BET1+BET2
IF (H2.GE.H1) GO TO 23
EET=BETA+2.*EET2
CB1=BETA-BET1
LE2=BET-BETA
LB3=ABS (BMIN-BETA)
IF (((DB3.GT.DB1.OR.DB3.GE.DB2).AND.DB2.GT.DE1) B1=BET1
IF (DB3.GT.LB1.OR.DB3.GE.DB2).AND.DB2.GT.DB1) LEN=0
IF (DB3.GT.LB1.OR.DB3.GE.DB2).AND.DB2.GT.DB1) FBT=FBT1
IF (DB3.LE.LB1.OR.DB2.LE.DB1).AND.DB3.LE.DE1) B1=BET1+BET2
IF (DB3.LE.LB1.OR.DB2.LE.DB1).AND.DB3.LE.DE1) FBT=FBT1+FBT2+
IF (DB3.GE.LE2.AND.DB2.LE.DB1) B1=BET
IF (DB3.GE.LE2.AND.DB2.LE.DB1) LEN=1
IF (DB3.GE.LE2.AND.DB2.LE.DB1) FBT=FBT1+2.*(FBT2+FBT3)
GO TO 26
B1=2.0*(BET1+BET2)
LEN=1
FBT=2.0*(FBT1+FBT2+FBT3)
WRITE (6,401) J,B1,FBT,FBT1,FBT2,FBT3,FX1,YN1
IF (CKZERO (H2-H1)) GO TO 26
IP=103
IF (NP1.EQ.1) J1=J1+1
SPHI= SIN(ANGLE)
IF (Z (J1+1).LE.H2) CALL POINT (H2,YN,N,NP,FX,IP)
IF (Z (J1+1).LE.H2) J2=J1

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19

20

*

23


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DATA      PI /3.14159265358979/
*** THE CCNVERSION FROM DEGREES TO RADIANS.
DATA      CA /0.017453292519943/
*** THE MEAN RADIUS OF THE EARTH (INTERNATIONAL SPHERIOD) IN KM.
DATA      REBAR /6371.299315/
*** THE POLAR RADIUS OF THE EARTH (INTERNATIONAL SPHEROID) IN KM.
DATA      REPOL /6356.911946/
*** THE EQUATORIAL RADIUS OF THE EARTH (INTERNATIONAL SPHEROID) IN KM.
DATA      REEQU /6378.388000/
*** VALUES OF THE RADIUS OF THE EARTH FOR THE MODEL ATMOSPHERES IN KM.
DATA      REARTH{1} /6376.951637/
DATA      REARTH{2} /6367.659029/
DATA      REARTH{3} /6367.659029/
DATA      REARTH{4} /6362.287754/
DATA      REARTH{5} /6362.287754/
DATA      REARTH{6} /6367.659029/
DATA      REARTH{7} /6371.299315/
*** NUMBER OF TYPES OF MODEL ATMOSPHERES
DATA      IATM /6/
*** NUMEER OF LEVELS IN MODEL ATMOSPHERE DATA
DATA      NL /34/
*** HAZE MODEL, 23 KM. VISIBLE RANGE
DATA      HZ1 /2.830E+03,1.245E+03,5.374E+02,2.257E+02,
* 1.193E+02,8.992E+01,6.341E+01,5.893E+01,5.822E+01,
* 5.679E+01,5.320E+01,5.589E+01,5.159E+01,5.052E+01,4.747E+01,
* 4.514E+01,4.460E+01,4.317E+01,3.636E+01,2.669E+01,1.935E+01,
* 1.456E+01,1.114E+01,8.831E+00,7.434E+00,5.893E-01,
* 1.551E-01,4.084E-02,1.078E-02,5.553E-05,1.970E-08,0.000E+00/
*** HAZE MODEL, 5 KM. VISIBLE RANGE

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DATA      HZ2 /1.379E+04,5.034E+03,1.845E+03,6.735E+02,
* 2.454E+02,8.992E+01,6.341E+01,5.893E+01,5.822E+01,
* 5.679E+01,5.320E+01,5.589E+01,5.159E+01,4.747E+01,
* 4.514E+01,4.460E+01,4.317E+01,3.633E+01,1.933E+01,
* 1.456E+01,1.114E+01,8.831E+00,2.239E+00,1.589E+00,
* 1.551E-01,4.084E-02,1.078E-02,5.553E-05,1.970E-08,0.000E+00/
C *** ALTITUDE (KM.) AT LEVEL I
C
DATA      Z0 /0.0,1.0,2.0,3.0,4.0,5.0,6.0,7.0,8.0,
* 9.0,10.0,11.0,12.0,13.0,14.0,15.0,16.0,17.0,18.0,19.0,20.0,
* 21.0,22.0,23.0,24.0,25.0,30.0,35.0,40.0,45.0,50.0,70.0,
* 100.0,999.0/
C *** PRESSURE (MB.) AT LEVEL I FOR THE MODEL ATMOSPHERES
C
DATA      P01
* 7.150E+02,6.330E+02,5.590E+02,4.920E+02,4.320E+02,3.805E+02,
* 3.290E+02,2.860E+02,2.470E+02,2.130E+02,1.820E+02,1.560E+02,
* 1.320E+02,1.110E+02,9.370E+01,7.890E+01,6.660E+01,5.650E+01,
* 4.800E+01,4.090E+01,3.500E+01,2.570E+01,1.220E+01,
* 6.000E+00,3.050E+00,1.590E+00,8.540E-01,5.790E-02,3.000E-04,
* 0.000E+00/
DATA      P02
* 7.100E+02,6.280E+02,5.540E+02,4.870E+02,4.260E+02,3.802E+02,
* 3.240E+02,2.810E+02,2.430E+02,2.090E+02,1.790E+02,1.530E+02,
* 1.300E+02,1.110E+02,9.500E+01,8.120E+01,6.950E+01,5.950E+01,
* 5.100E+01,4.370E+01,3.760E+01,2.220E+01,1.320E+01,
* 6.520E+00,3.330E+00,1.760E+00,9.510E-01,6.710E-02,3.000E-04,
* 0.000E+00/
DATA      P03
* 6.938E+02,6.081E+02,5.313E+02,4.622E+02,4.018E+02,3.597E+02,
* 2.992E+02,2.568E+02,2.199E+02,1.882E+02,1.610E+02,1.378E+02,
* 1.178E+02,1.007E+02,8.610E+01,7.350E+01,6.280E+01,5.370E+01,
* 4.580E+01,3.910E+01,3.340E+01,2.860E+01,2.430E+01,1.110E+01,
* 5.180E+00,2.530E+00,1.290E+00,6.820E-01,4.670E-02,3.000E-04,
* 0.000E+00/
DATA      P04
* 7.000E+02,6.160E+02,5.410E+02,4.730E+02,4.101E+02,3.600E+02,
* 3.107E+02,2.677E+02,2.300E+02,1.977E+02,1.700E+02,1.460E+02,
* 1.250E+02,1.080E+02,9.280E+01,7.980E+01,6.860E+01,5.890E+01,
* 5.070E+01,4.360E+01,3.750E+01,3.227E+01,2.780E+01,1.340E+01,
* 6.610E+00,3.400E+00,1.810E+00,9.870E-01,7.070E-02,3.000E-04,
* 0.000E+00/
DATA      P05
* 6.798E+02,5.932E+02,5.158E+02,4.467E+02,3.853E+02,3.308E+02,
* 2.829E+02,2.418E+02,2.067E+02,1.766E+02,1.510E+02,1.291E+02,
*

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* 0-51, 0-63, 0-69, 0-86, 1-06, 1-54, 2-00, 2-50, 2-70, 3-00,
* 3-20, 3-39, 3-50, 3-75, 4-00, 4-50, 5-50, 6-50, 6-59, 7-20,
* 7-90, 8-20, 8-50, 8-70, 9-00, 9-20, 9-50, 10-00, 10-59, 11-00,
* 13-00, 14-80, 15-00, 17-20, 18-50, 20-00, 25-00, 27-90, 30-00,
*** RURAL AEROSOL MODEL
C C C
DATA VX02 0-69, 0-86, 1-06, 1-54, /0-20, 1-80, 2-50, 3-00, 3-40, 0-48,
* 0-55, 4-00, 5-00, 5-50, 6-00, 7-20, 8-20, 8-50, 8-70, 9-00,
* 3-75, 9-20, 9-50, 9-80, 10-00, 10-59, 11-50, 12-50, 13-00,
* 14-00, 15-00, 16-40, 17-20, 18-50, 20-00, 22-50, 25-00, 30-00,
*** URBAN AEROSOL MODEL
C C C
DATA VX03 0-69, 0-86, 1-06, 1-54, /0-20, 1-80, 2-50, 3-00, 3-40, 0-49,
* 0-55, 4-00, 5-00, 5-50, 6-00, 7-20, 8-20, 8-50, 8-70, 9-00,
* 3-75, 9-20, 9-50, 9-80, 10-00, 10-59, 11-50, 12-50, 13-00,
* 14-00, 15-00, 16-40, 17-20, 18-50, 20-00, 22-50, 25-00, 30-00,
*** MARITIME AEROSOL MODEL
C C C
DATA VX04 0-69, 0-86, 1-06, 1-54, /0-20, 1-80, 2-50, 3-00, 3-40, 0-49,
* 0-55, 4-00, 5-00, 5-50, 6-00, 7-20, 8-20, 8-50, 8-70, 9-00,
* 3-75, 9-20, 9-50, 9-80, 10-00, 10-59, 11-50, 12-50, 13-00,
* 14-00, 15-00, 16-40, 17-20, 18-50, 20-00, 22-50, 25-00, 30-00,
*** TRANSMITTANCE FUNCTIONS
C C C
DATA TR /0-99, 0-998, 0-996, 0-992, 0-990, 0-990, 0-990, 0-980,
* 0-970, 0-960, 0-950, 0-940, 0-930, 0-920, 0-910, 0-900, 0-880,
* 0-840, 0-820, 0-800, 0-780, 0-760, 0-740, 0-720, 0-700, 0-680,
* 0-640, 0-620, 0-600, 0-580, 0-560, 0-540, 0-520, 0-500, 0-460,
* 0-440, 0-420, 0-400, 0-380, 0-360, 0-340, 0-320, 0-300, 0-260,
* 0-240, 0-220, 0-200, 0-180, 0-160, 0-140, 0-120, 0-100, 0-060,
* 0-040, 0-030, 0-020, 0-015, 0-010, 0-008, 0-006, 0-004, 0-002, 0-001,
*** TRANSMITTANCE FUNCTION FOR H2O
C C C
DATA FW -1-2007, -0-7825, -0-5229, -0-3468, -2-0362, -1-6990, -1-4815, -1-3279,
* -1-2430, 0-3324, 0-4342, -0-3468, -0-1938, 0-0655, 0-0414, 0-1553,
* 0-0792, 1-1461, 1-2122, 0-6128, 0-7243, 0-8261, 0-9191, 1-0000,
* 1-5441, 1-5966, 1-6435, 1-6857, 1-7340, 1-7782, 1-8261, 1-8692,
* 1-9191, 1-9638, 2-0086, 2-0607, 2-1038, 2-1461, 2-1875, 2-2304,

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***
-0.68,-0.73,-0.85,-0.85,-0.61,-0.74,-0.48,-0.51,-0.92,-0.83,
-0.61,-0.41,-0.29,-0.29,-0.61,-0.74,-0.19,-0.18,-0.00,0.19,
-0.10,-0.20,-0.02,-0.02,-0.20,-0.00,-0.18,-0.28,-0.11,-0.00,
-0.37,-0.10,-0.11,-0.11,-0.16,-0.09,-0.00,-0.37,-0.28,-0.07,
0.22,-0.09,-0.19,-0.23,-0.69,-0.21,-0.29,-0.52,-0.54,-0.19,
0.19,-0.19,-0.23,-0.49,-0.48,-0.29,-0.27,-0.33,-0.81,-0.60,
0.40,-0.40,-0.49,-0.49,-0.48,-0.46,-0.49,-0.27,-0.06,-1.17,

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C

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DATA C114
-1.11,-1.37,-1.52,-1.54,-1.94,-2.06,-2.31,-2.14,-1.96,0.00,
-2.00,-2.08,-2.23,-2.31,-2.31,-2.31,-2.31,-2.31,-2.31,-2.28,
-2.34,-2.34,-2.34,-2.34,-2.34,-2.34,-2.34,-2.34,-2.34,-2.34,
-1.76,-1.54,-1.44,-1.44,-1.48,-1.48,-1.48,-1.48,-1.48,-1.36,
-1.36,-1.44,-1.44,-1.48,-1.48,-1.48,-1.48,-1.48,-1.48,-1.40,
-1.23,-1.18,-1.37,-1.37,-1.32,-1.32,-1.32,-1.32,-1.32,-1.30,
-2.42,-2.58,-2.58,-2.58,-2.58,-2.58,-2.58,-2.58,-2.58,-2.07,
-1.23,-1.10,-1.10,-1.10,-1.10,-1.10,-1.10,-1.10,-1.10,-1.16,
-0.97,-0.91,-0.91,-0.91,-0.91,-0.91,-0.91,-0.91,-0.91,-0.97,
-3.91,-4.20,-4.49,-4.78,-5.07,-5.07,-5.07,-5.07,-5.07,-2.63,

```

C C C

*** SPECTRAL DATA' UNIFORMLY MIXED GASES

```

DATA C201
-4.25,-3.70,-3.51,-3.51,-3.51,-3.51,-3.51,-3.51,-3.51,-3.51,
-0.71,-0.51,-0.91,-0.91,-0.91,-0.91,-0.91,-0.91,-0.91,-0.91,
3.56,3.69,3.73,3.73,3.73,3.73,3.73,3.73,3.73,3.73,
2.86,2.92,2.92,2.92,2.92,2.92,2.92,2.92,2.92,2.92,
1.21,0.18,-0.18,-0.18,-0.18,-0.18,-0.18,-0.18,-0.18,-0.18,
-1.00,-1.00,-1.00,-1.00,-1.00,-1.00,-1.00,-1.00,-1.00,-1.00,
-3.14,-5.00,-5.68,-5.68,-5.68,-5.68,-5.68,-5.68,-5.68,-5.68,
-5.00,-2.11,-2.11,-2.11,-2.11,-2.11,-2.11,-2.11,-2.11,-2.11,
-2.09,-2.83,-2.83,-2.83,-2.83,-2.83,-2.83,-2.83,-2.83,-2.83,
-0.51,-0.91,-0.91,-0.91,-0.91,-0.91,-0.91,-0.91,-0.91,-0.91,
-2.11,-2.74,-2.74,-2.74,-2.74,-2.74,-2.74,-2.74,-2.74,-2.74,
-1.13,-1.17,-1.17,-1.17,-1.17,-1.17,-1.17,-1.17,-1.17,-1.17,
-1.20,-1.17,-1.17,-1.17,-1.17,-1.17,-1.17,-1.17,-1.17,-1.17,
0.57,0.77,0.77,0.77,0.77,0.77,0.77,0.77,0.77,0.77,
1.44,1.40,1.40,1.40,1.40,1.40,1.40,1.40,1.40,1.40,
0.82,0.68,0.68,0.68,0.68,0.68,0.68,0.68,0.68,0.68,
-2.81,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,-5.00,

```

C

```

DATA C202
-1.69,-1.82,-1.87,-1.90,-1.94,-2.04,-2.10,-2.23,-2.32,-2.48,

```


APPENDIX B

CONTINUED DATA PACKAGE

[illegible]

90

09	18	13	18	7	0	0	0	0	0	0	0	0	2	2	8	9	0	0	4	0	3	9	7	8	1	2	4	2	0	2	0			
2	7	1	6	1	9	0	0	0	0	0	0	0	2	1	4	0	5	3	0	9	5	4	7	6	3	6	7	9	2	0				
3	2	2	4	1	0	1	5	5	5	5	5	5	3	4	4	2	5	4	3	5	4	1	1	2	4	4	0	0	0	5				
9	2	0	0	8	7	2	0	0	0	0	0	0	4	7	1	7	0	7	1	0	0	3	5	1	2	0	2	1	8	3	0			
1	0	0	0	9	3	0	0	0	0	0	0	0	3	6	5	0	8	4	0	0	8	3	6	3	0	8	6	9	7	0				
3	3	2	5	1	0	1	5	5	5	5	5	5	3	4	2	5	4	3	5	4	1	1	2	4	5	0	0	0	5	1				
9	9	6	0	0	5	1	0	0	0	0	0	0	5	4	0	5	0	0	9	0	0	8	9	7	5	0	2	2	8	3	0			
8	1	0	0	2	6	4	3	0	0	0	0	0	5	4	0	5	0	0	4	0	0	0	1	4	1	0	0	5	0	1	0			
2	3	2	5	2	0	0	4	5	5	5	5	5	3	4	2	5	4	3	5	4	1	1	2	4	5	1	0	1	1	5				
1	7	9	0	1	8	3	3	0	0	0	0	0	8	8	0	8	6	0	1	0	0	3	8	3	8	0	6	9	7	8	0			
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9	5	4	0	7	8	1	5	0	0	0	0	0	9	0	0	6	4	0	5	5	0	7	9	1	8	0	3	2	2	7	0			
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0	7	3	0	0	9	1	3	0	0	0	0	0	3	1	0	7	0	0	5	2	0	0	7	0	6	0	5	0	1	7	0			
3	3	2	5	3	0	0	4	5	5	5	5	5	4	3	5	2	7	5	4	5	3	0	2	3	5	1	0	1	1	5				
6	9	2	1	8	3	0	1	6	2	0	0	0	0	7	1	8	0	6	2	0	5	8	7	0	2	9	4	0	8	0	0			
3	3	2	4	3	1	0	4	5	5	5	5	5	4	3	5	2	2	5	3	5	3	0	1	3	5	1	0	1	1	5				
1	8	2	5	7	2	6	1	0	0	0	0	0	0	2	0	7	8	0	6	0	0	7	8	0	8	0	2	4	2	7	8	0		
4	3	2	3	3	1	0	4	5	5	5	5	5	3	5	3	2	5	3	5	3	0	1	3	5	2	0	1	1	3	5				
2	2	6	1	9	8	4	1	0	0	0	0	0	5	0	8	8	0	7	0	0	2	6	0	0	9	3	6	3	7	0				
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4	3	2	2	3	1	0	3	5	5	5	5	5	3	5	3	2	5	3	5	4	1	1	3	4	2	0	0	1	1	5				
8	1	3	6	2	4	7	5	7	0	0	0	0	0	2	6	8	3	2	0	2	3	4	0	1	2	5	7	1	2	4	8	5	1	0
4	3	2	2	4	1	0	2	5	5	5	5	5	3	4	3	2	5	4	3	5	4	1	1	2	4	3	0	0	0	0	5			

APPENDIX C
SAMPLE OUTPUT

SUB-ARCTIC (60 DEG. LAT.) WINTER MODEL ATMOSP RE
CONTINENTAL AEFCSQ MODEL
HAZE MODEL = 23.0 KM VISUAL RANGE AT SEA LEV L
H1 = 2.500 KP, H2 = 8.500 KM, ANGLE = 65.0000 GEOM. RANGE = 14.15 KM, BETA = 0.11537 DEG
SLANT PATH BETWEEN ALTITUDES H1 AND H2 WHERE H1 2.500 KM H2 = 8.500 KM, ZENITH ANGLE = 65.000 DEGREES
FREQUENCY RANGE V1 = 2350.0 CM-1 TO V2 = 2450.0 CM-1 FOR DV = 5.0 CM-1 (4.08 - 4.26 MICRONS)

	VERTICAL PROFILES										BLTA		PMTA		RANGE	
3	2.5	7.270E-02	7.290E-01	2.051E-03	5.419E-01	3.763E-04	9.090E-01	1.456E-01	2.309E-03	-0.0001	115.0397	04.9949	1.2			
4	3.0	1.595E-01	1.290E+00	9.150E-03	1.352E+00	7.720E-04	2.528E+00	2.451E-01	7.164E-03	0.0021	115.0268	04.9925	3.3			
5	4.0	2.018E-01	1.264E+00	1.021E-02	2.055E+00	9.320E-04	3.969E+00	3.730E-01	1.222E-02	0.0046	115.0432	04.9757	5.3			
6	5.0	2.203E-01	1.344E+00	1.425E-02	2.583E+00	9.887E-04	5.256E+00	4.385E-01	1.751E-02	0.0069	115.0604	04.9588	8.3			
7	6.0	2.288E-01	1.426E+00	1.697E-02	2.992E+00	1.011E-03	6.402E+00	4.500E-01	2.405E-02	0.0093	115.0772	04.9417	10.3			
8	7.0	2.316E-01	1.476E+00	2.500E-02	3.308E+00	1.017E-03	7.415E+00	5.397E-01	3.285E-02	0.0110	115.0946	04.9244	13.0			
9	8.0	2.320E-01	1.497E+00	2.878E-02	3.428E+00	1.018E-03	7.876E+00	5.648E-01	3.860E-02	0.0124	115.1031	04.9066	14.2			

ESTIMATED TANGENT ALTITUDE = 920763.250 KM

EQUIVALENT SEA LEVEL ABSORBER AMOUNTS

	WATER VAPOR CM CM-2	CO2 ETC. KM	OZONE ATM CM	NITROGEN (CONT) KM	H2O (CONT) GM CM-2	WOL SCAT KM	AEROSOL KM	CLONE(U-V) ATM CM
W(1-8) =	2.220E-01	4.977E+00	2.878E-02	3.438E+00	1.018E-03 6.013E-02	7.876E+00	5.648E-01	3.860E-02

APPENDIX D DEFINITIONS AND SYMBOLS

AB	Absorption at frequency ν ; also average transmittance
AHZ1, AHZ2	Aerosol number density
AJ	Equivalent absorber amount per km at level J
ALP	Angle of arrival at adjacent level
ANGLE	Input zenith angle (degree)
BET	Angle subtended at the earth's center as path traverses adjacent levels
BETA	Total angle subtended path at earth's center
BJ	Equivalent absorber amount per km at level J+1
CA	Conversion factor from degree to radians
CO	Wavelength dependent coefficient used in refractive index expression
Cw	Wavelength dependent coefficient used in refractive index expression
C1	Log absorption coefficient for water vapor
C2	Log absorption coefficient for uniformly mixed gas
C3	Log absorption coefficient for ozone
C4	Absorption coefficient for nitrogen
C5	Absorption coefficient for water vapor continuum
C6	Extinction coefficient for molecular scattering
C7	Extinction coefficient for aerosol models
C7A	Aerosol absorption coefficient
C8	Absorption coefficient for ozone (UV and visible region)
D	water vapor amount (pr.cm/km) at level I
DP	Dew point temperature (C)
Ds	Path length from level I to level I + 1
DV	Wave number increment at which transmittance is calculated
DZ	Height increment from level I to I + 1
E(K)	Equivalent absorber amount per km at height H1
EH(1,I)	Equivalent absorber amount per km for water vapor at level Z(I)
EH(2,I)	Equivalent absorber amount per km for carbon dioxide, etc. at level Z(I)
EH(3,I)	Equivalent absorber amount per km for ozone at level Z(I)
EH(4,I)	Equivalent absorber amount per km for nitrogen at level Z(I)
EH(5,I)	Equivalent absorber amount per km for water vapor continuum at level Z(I)
EH(6,I)	Equivalent absorber amount per km for molecular scattering at level Z(I)
EH(7,I)	Equivalent absorber amount per km for waerosol extinction at level Z(I)
EH(8,I)	Equivalent absorber amount per km for ozone (UV and visible) at level Z(I)
EH(9,I)	Mean refractive index of layer above level Z(I)
EV	Integrated absorber amount from level I to I + 1
FAC	Factor for exponential and linear interpolation
FO	Transmissiion function logarithmic absorber amount scale for ozone
FW	Transmissiion function logarithmic absorber amount scale for water vapor and uniformly mixed gases
H	Altitude (km)
H1	Initial Altitude (km)
H2	Final Altitude (km)

HAZE	Aerosol number density (no. cm-3)
HM	Estimated tangent height (km)
HMIN	Minimum altitude of path trajectory (km)
HZ1	Aerosol number density (no. cm-3) for 23 km visual range
HZ1	Aerosol number density (no. cm-3) for 5 km visual range
I	Running integer used as altitude indicator
IAERO	Indicator for type of aerosol model
IATCM	Number of levels in model atmosphere
IDV	Frequency increment (cm-1)
IFIND	Indicator for using subroutine ANGL
IHAZE	Aerosol model indicator
IM	Parameter used when reading in a new atmospheric model
IP	Indicator for using subroutine POINT to calculate reference index only (IP = 0)
IR	Card printer number
ITER, IIES	Iteration counters
ITYPE	Indicator for type of atmospheric path
IV	Frequency at which transmittance is calculated
IV1	Starting frequency
IV2	Last frequency
IW	Line printer number
IXY	Parameter for terminating program and cycling indicator
J	Running integer for altitude identification
JMIN	Altitude indicator for minimum height of path
JP	Print option for altitude H1
J1	Level indicator for altitude H1
J2	Level indicator for altitude H2
K	Absorber indicator, K=1, 2, 3, etc., corresponds to water vapor, uniformly mixed gases, ozone, etc., respectively
K2	Cycling parameter for downward looking paths
L	Frequency indicator for ozone transmittance calculation
LEN	Parameter used for defining longest of two paths
M	Integer used to identify required model atmosphere
ML	Number of levels in radiosonde data input (MODEL7)
MODEL	Integer used to identify required model atmosphere
M1	Integer for selecting temperature altitude profile for (M=M1)
M2	Integer for selecting water vapor altitude profile for (M=M2)
M3	Integer for selecting ozone altitude profile for (M=M3)
N	Indicator for level below given input altitude used in PCINT subroutine
NL, NLF	Number of levels in model atmosphere data
NP	Indicator for determining whether H1 or H2 coincide with levels in the model atmosphere
NP1	Value of NP for altitude H1
NP2	Value of NP for altitude H2
NS1, NS2	Counters corresponding to WS1, WS2
P(M, 1)	Pressure (mb) at level I for model atmosphere M
PHI	Angle of arrival at H2
PPW	Partial pressure of water vapor (in atmosphere)
PS	Total pressure in atmospheres
PSI	Angular deviation of path from initial direction
PT	Product of total pressure (atm) and the square root of $273/T(M, I)$
RANGE	Path length (km)
RE, REATH	Earth radius (km)
REF	Refractive index of air at level I
RH	Relative humidity (%)
RN	Ratio of refractive indices of air above and

below a given level

RX Ratio of earth center distances between adjacent levels

RO Earth radius (km) read in as input (=RE)

R1 The product of the sine of the initial zenith angle and the earth center distance to starting altitude

SALP Sine of angle of arrival at adjacent level

SPHI Sine of the local zenith angle at a given level

SR Slant range (km)

SUM Accumulated absorption

T(M,I) Temperature (K) for model atmosphere M at level I

THET Zenith angle at a given level (in radians)

THETA Zenith angle at a given level (in degrees)

TMP Ambient temperature (C)

TR Transmittance scales for transmission functions

TS Ratio of standard temperature (273.15 K) to temperature level I

TS1 Ratio of 296 K to temperature at level I

TT Ratio 273.15/(TMP + 273.15)

TX(K) Equivalent absorber amounts per km at a given altitude obtained from POINT; also transmittance values at a given wavelength for each absorber type (K = 1,8)

TX(9) Total transmittance at frequency IV

TX(10) Absorption due to aerosol only at frequency IV

TX1 Refractive index of layer above initial alt. H1

TX2 Refractive index of layer above final alt. H2

TX1 Refractive index of layer above minimum alt. HMIN

VH(K) Integral of the equivalent absorber amounts from H1 to level I

VIS Visual range (km) at sea level

VX Wavelength at which aerosol coefficients are read in (micrometer)

V1 Initial frequency for transmittance calculation

V2 Final frequency for transmittance calculation

W(K) Total equivalent absorber amount for entire path

WH(M,I) Water vapor density for atmospheric model M at level I (gm m⁻³)

WL, WL1, WL2 Wavelength in microns

WO(M,I) Ozone density for atmospheric model M at level I

WS1 Transmission function scaling factor for water vapor at given wavelength

WS2 Transmission function scaling factor for carbon dioxide, etc., at given wavelength

WS3 Transmission function scaling factor for ozone at given wavelength

X Input height to POINT subroutine

XI Wavenumber interpolation parameter

XX Wavenumber identification parameter for UV ozone transmittance calculation

X1 Earth center distance of level I

X2 Earth center distance of level I + 1

YN Refractive index of layer below input height from POINT subroutine

YN1 Refractive index of layer below initial alt. H1

YN2 Refractive index of layer below final alt. H2

YY Aerosol absorption coefficient at frequency V

Z(I), ZO(I) Altitude at level I in km

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